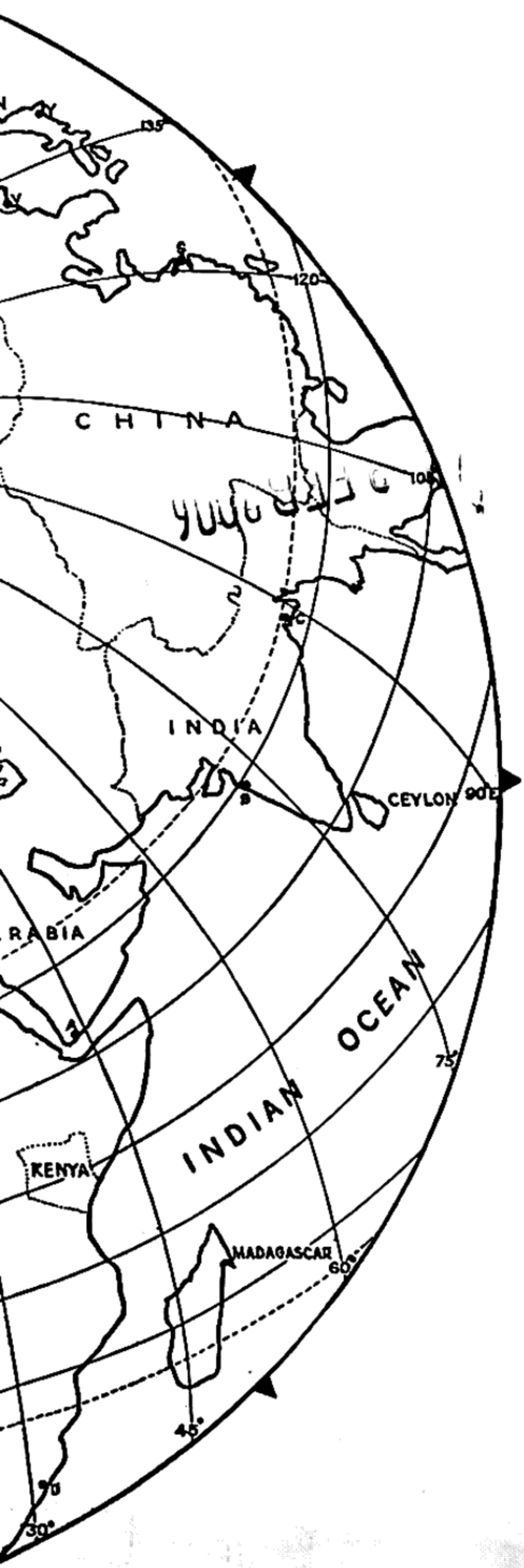


AN AIR MAP

This map is drawn in such a way that an airman can find on it the shortest route from Britain to any of the countries shown.

If he wishes to go from London to Ceylon he will draw a straight line from that city to the nearest point of the island. This line will cross Germany, Russia, and India, gradually changing its compass direction from east to south-east as it proceeds.

He can then measure the distance by means of the scale. From London to the coast of Ceylon is 5,300 miles. Test this with a sli . of paper.

POINT TO ARABIA

In which direction does Arabia lie ? Turn this book until the lower edge of the page is towards the south. Then lay a pencil on it, crossing Britain and Arabia, and the pencil will point to Arabia itself.

WIRELESS

The direction of any wireless station on the map can also be found for any place in Britain and a " direction dial " drawn.

A number of broadcasting stations are marked with a cross (+).

TO THE READER.

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BY

E. J. ORFORD

AUTHOR OF "JUNIOR PRACTICAL GEOGRAPHY," "EXERCISES ON ORDNANCE SURVEY MAPS"

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T. R. JEREMIAH
AND OTHER ILLUSTRATIONS

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PREFACE

SENIOR PRACTICAL GEOGRAPHY was planned in the first instance at the suggestion of Mr. Leonard Brooks to meet the request of many teachers, who had attended the author's lectures and demonstrations, for a book on the subject.

The exercises are suitable for pupils from eleven years and upward, the upper limit being conditioned by circumstances. In a school where special emphasis was laid on practical work, they have been carried out by boys up to the age of fourteen, though not by all of that age. In another school they were used for pupils up to sixteen.

The material dealt with is of a fundamental character, and the book contains nothing beyond what is assumed necessary for the ordinary understanding of geography ; in fact, a number of rather important topics had to be ruled out for reasons of space.

In the section on the movements of the Earth and the moon, attention is directed rather to the observation of the actual phenomena than to the diagrams representing them ; and if more space than usual is given to map projection, it is because the subject has proved very popular and at the same time very profitable, since it compels such constant comparison between the map and the globe. This is a matter of no small importance to the new generation which is growing up in a world where, already, long-distance air flights and " beam wireless " have become commonplace ; and neither of these can be understood on the map until they have been fully appreciated on the globe.

The range of statistics under Weather and Climate has been extended to include extracts from the daily weather

reports of a number of stations. This has been done in order to modify such an impression of the even rise and fall of temperature as is apt to be engendered by too great an adherence to the graphing of average monthly figures.

My thanks are again due to Miss H. M. C. Coutts for her help in reading the proofs, and to Mr. T. R. Jeremiah for his great care over the details of the diagrams ; to Mr. S. Wyles for his great patience in the preparation and taking of the photographs, and to Messrs. A. E. Orford and Leonard Brooks for many valuable suggestions when the book was reaching its final form.

The exercises throughout the book have been marked A, B, C, or D according to difficulty, as in the Junior Practical Geography.

E. J. O.

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PART I

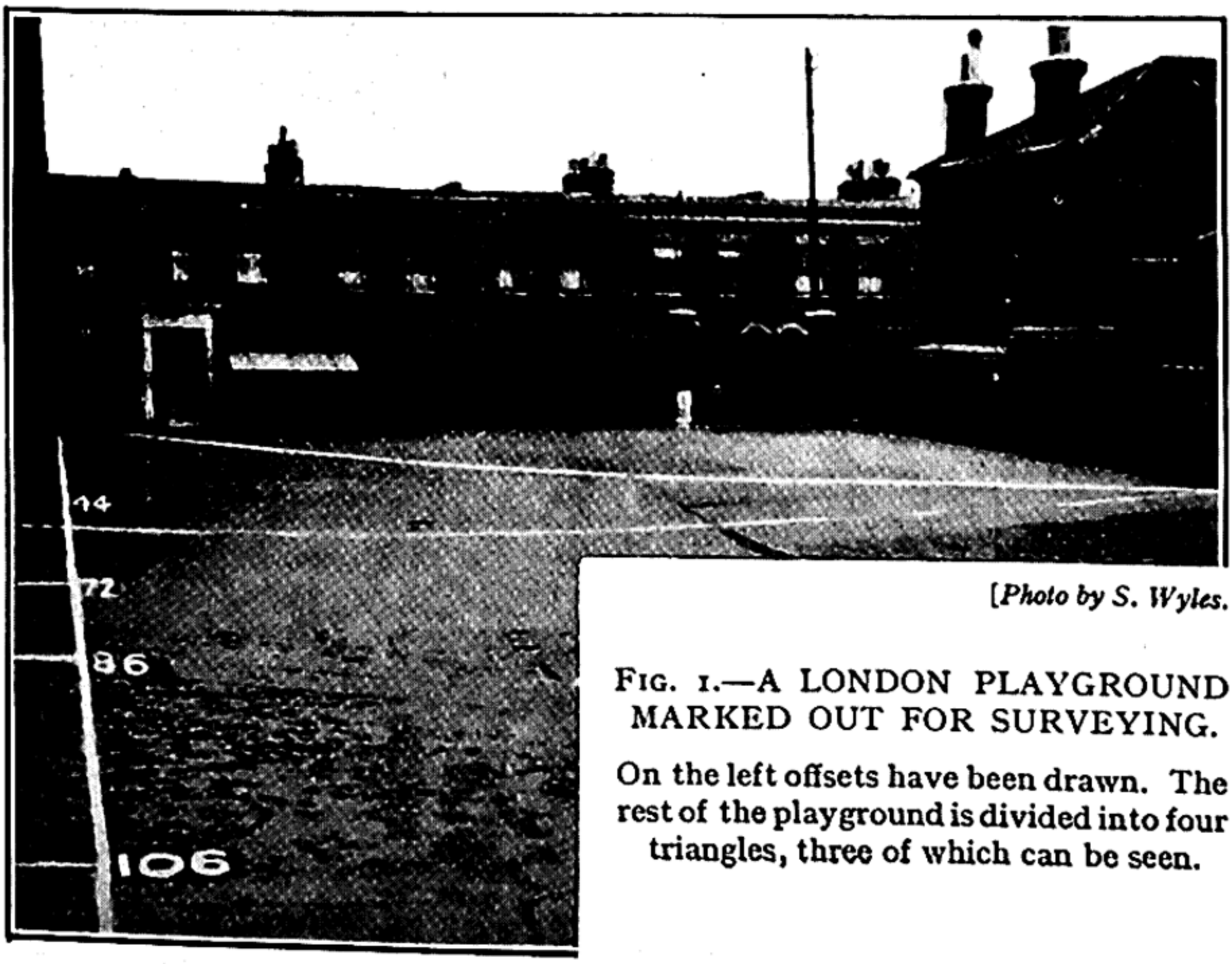
INTRODUCTION

Chapter One

MAP MAKING

THE PLAN OF A PLAYGROUND

PLAYGROUNDS are generally rather difficult to draw to scale, for their corners are not always right angles, and one side at least, the one formed by the school buildings, is likely to have a number of " ins " and " outs " that are awkward to measure and put on paper.



[*Photo by S. Wyles.*

FIG. 1.—A LONDON PLAYGROUND MARKED OUT FOR SURVEYING.

On the left offsets have been drawn. The rest of the playground is divided into four triangles, three of which can be seen.

The method of drawing the plan of such a playground can best be understood from the picture. A straight line has been drawn to cut off all the difficult parts on the left side, leaving an area with four straight sides on the right. This area is then divided into four triangles, and the irregular side is surveyed by means of " offsets," which are the lines in the picture running off to the left.

TRIANGULATION

Four strips of wood of equal length can be nailed together at the corners so as to form a square, each angle being a right angle. But if the square is pressed from one side it loses its shape and becomes a rhombus with two angles larger than right angles and two smaller.

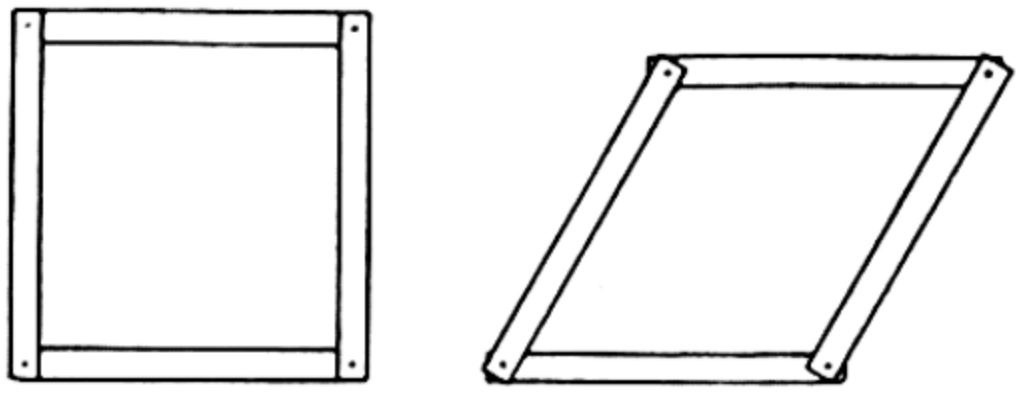


FIG. 2.—SQUARE AND RHOMBUS.

If three of the strips, however, be nailed together to form an equilateral triangle, there is no alteration in shape or in the size of the angles when pressure is applied.

Again, if any triangle be copied with its sides twice, three times, or any number of times as large (or small), its shape remains the same, and its angles are not altered.

This can be understood from Fig. 3, where the triangle with the thick sides was drawn first, the larger triangle being drawn afterwards with sides twice as long. With the help of a piece of tracing-paper, compare its angles with those of the first; then test those of the small triangle, the sides of which are half as long as those of the first.

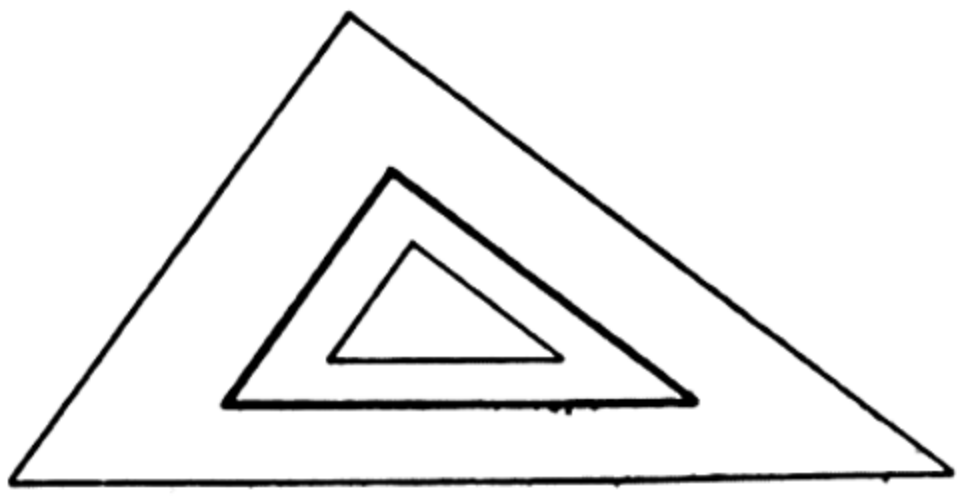


FIG. 3.—SIMILAR TRIANGLES.

It is because of these properties of the triangle that large

surveys are made by " triangulation." The country to be mapped is divided into a number of triangles whose sides, angles, and areas can be readily and accurately measured or computed. These triangles are then drawn to scale on paper, and the rivers, roads, towns, and other features made to fit into them as they do in the country itself.

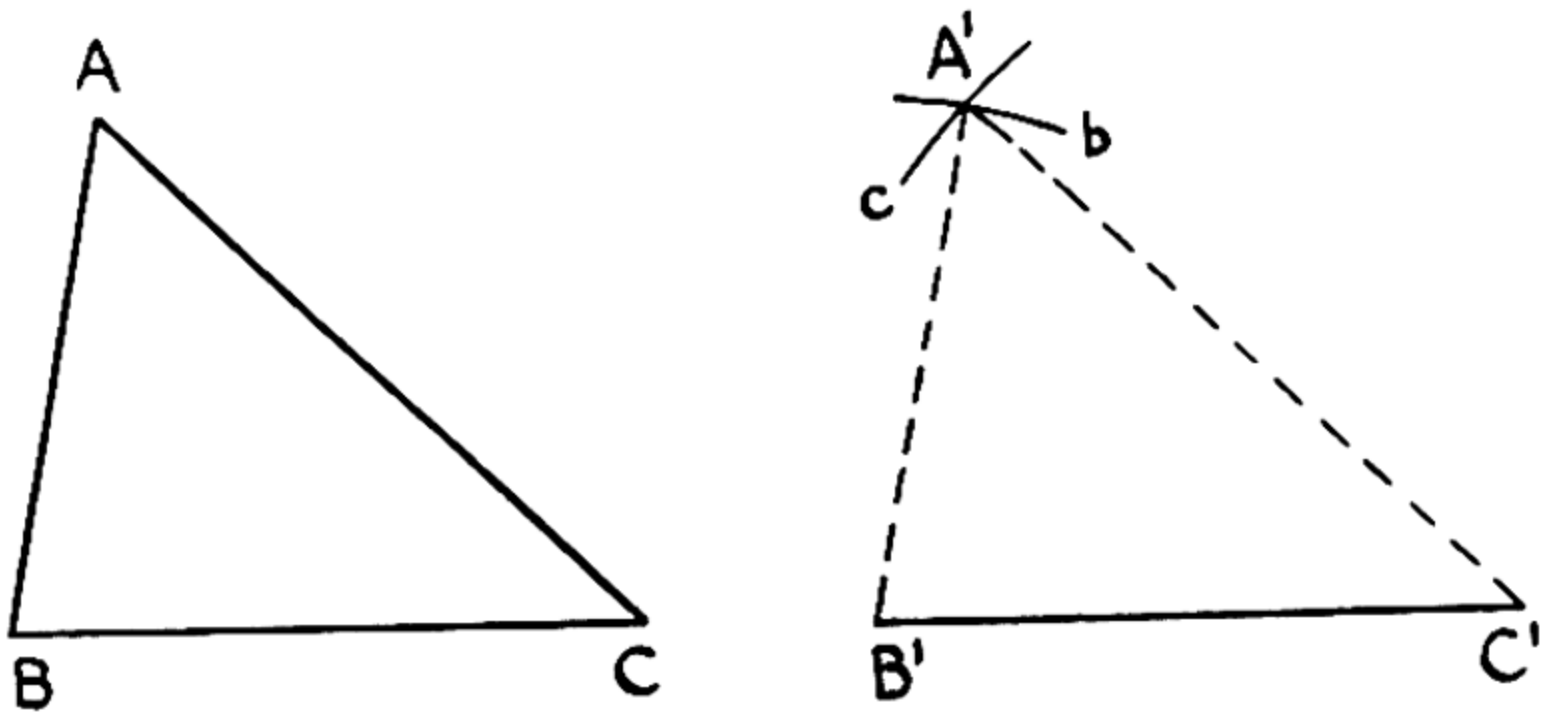


FIG. 4.—COPYING A TRIANGLE.

PRELIMINARY EXERCISES

A. 1. *Copy the Triangle ABC.*

Draw the base B′C′ the correct length.

Measure BA with a pair of compasses, and with centre B′ draw the arc *b*.

Measure CA, and with centre C′ draw the arc *c*.

A′ is where the arcs intersect.

Join B′A′, C′A′.

A. 2. *Copy the Figure DEFG.*

Join DF to convert the figure into two triangles.

Draw the base D′E′ the correct length.

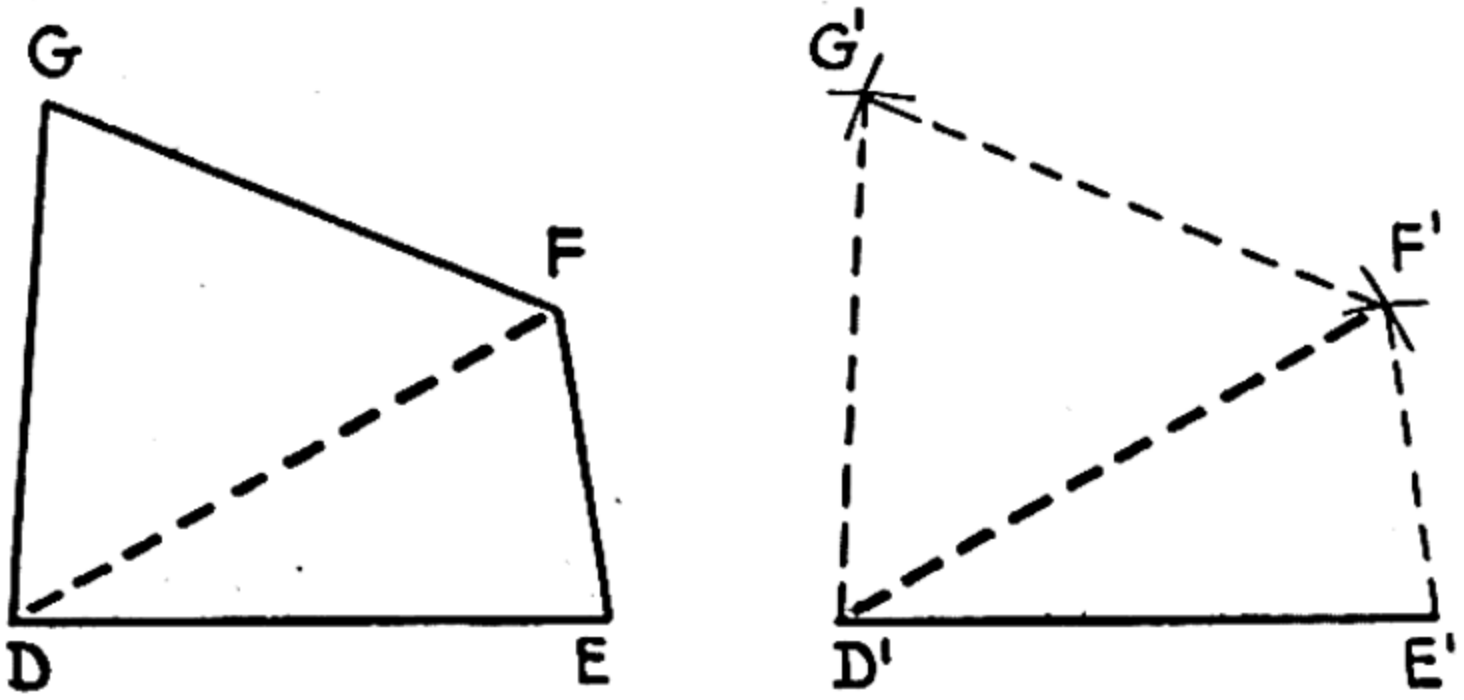


FIG. 5.—COPYING A QUADRILATERAL.

Construct the triangle D′E′F′ as shown in Fig. 4.
Measure FG, and with centre F′ draw an arc.
Measure DG, and with centre D′ draw another arc cutting it.
The arcs intersect at G′. Join D′G′, F′G′.

A PLAYGROUND

Here is a playgound that can be divided up into four triangles.

A. 3. Copy the plan of the playground.

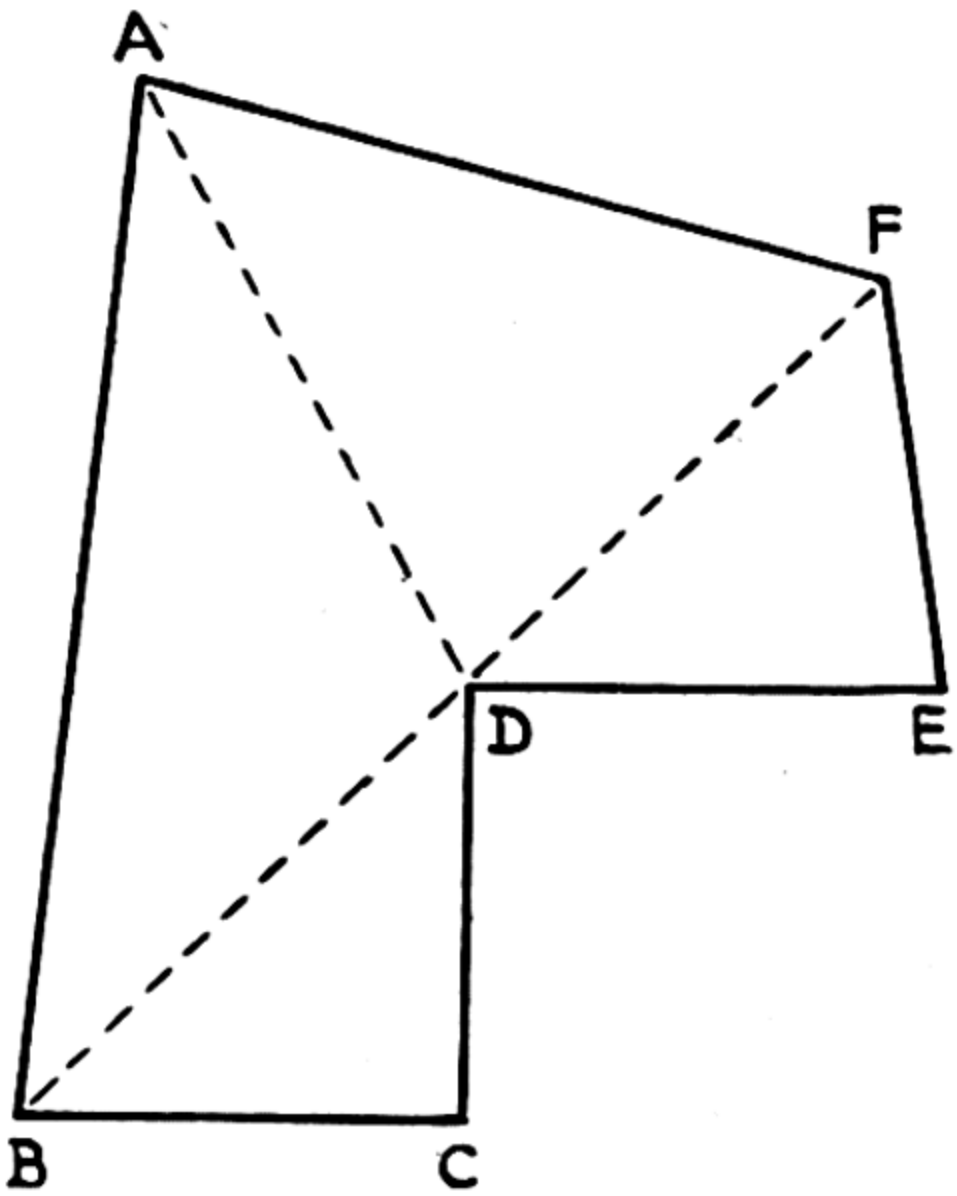


FIG. 6.—A PLAYGROUND DIVIDED INTO FOUR TRIANGLES.

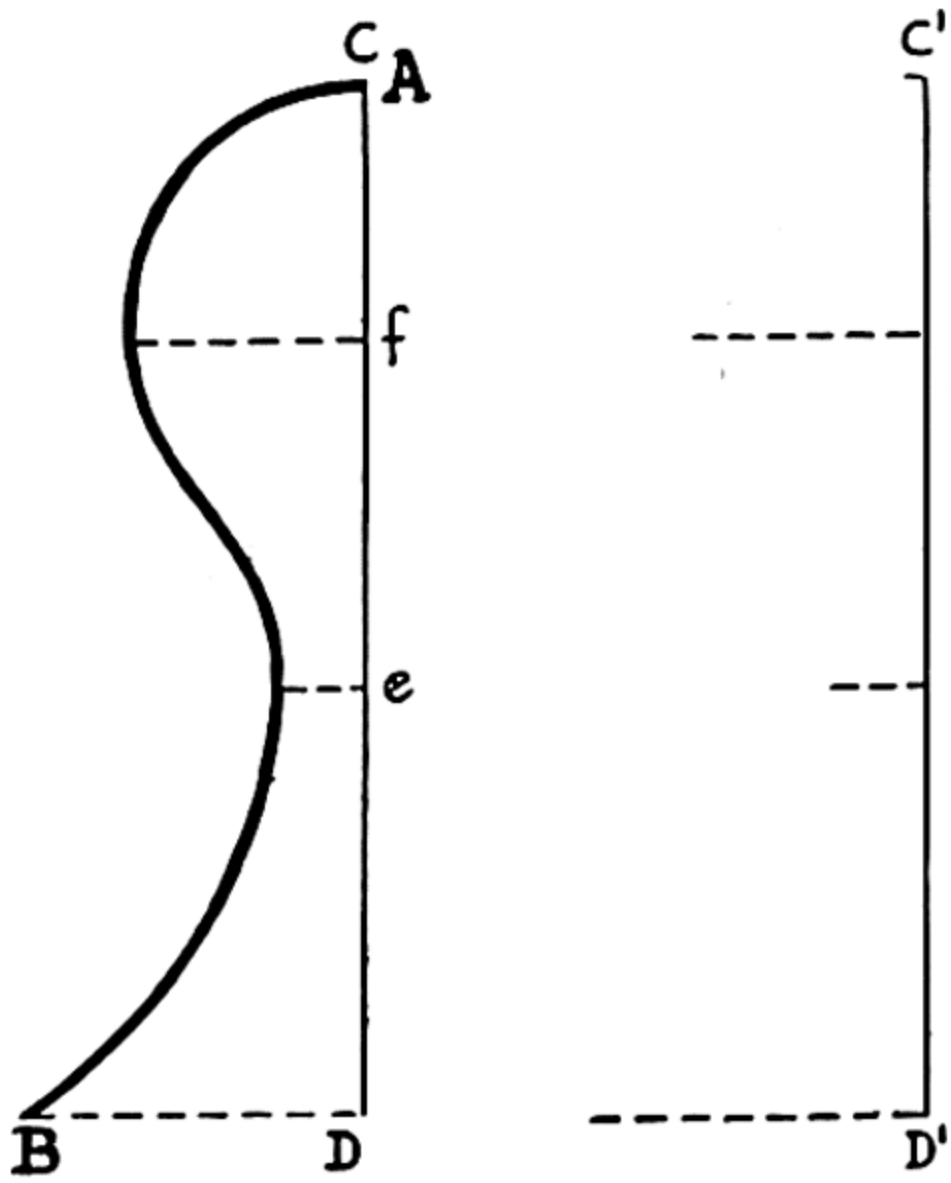


FIG. 7.—OFFSETS.

OFFSETS

To draw an irregular line such as the side of the playground in Fig. 1, or the course of a stream, we lay down a straight line roughly parallel to its general direction, and by means of offsets measure its distance from a number of places on that line. The offsets are perpendicular to the straight line, and their positions on that line are all measured from one end.

B. 1. Copy the thick curved line AB by drawing first the straight line C′D′ and then the offsets. Measure the distances of the offsets from C and mark them off from C′; then make them correct in length.

B. 2. Draw the irregular side of the playground in Fig. 10, using a scale either of 20 feet to an inch or a millimetre to a foot.

THE CHAIN AND TAPE

The chain used for surveying, called Gunter's Chain, is 66 feet long, and is divided into 100 links. Each link is 8 inches long or, more correctly, 7·92 inches.

Instead of having numbers, as there are on a tape measure, the chain has a brass tab or teller fastened to it at every tenth link, and, according to its position, the teller has one, two, three, or four points.

1 point	. .	10 or 90 links
2 points	. .	20 or 80 links
3 points	. .	30 or 70 links
4 points	. .	40 or 60 links.



FIG. 8.—GUNTER'S CHAIN.

Find tabs with 1, 2, 3, and 4 points. The rounded one showing below the "3" is at 50.

At 25, 50, and 75 there are swivel joints that prevent the chain from kinking; these also help in counting.

The handles are parts of the end links, and measurements are made from their outside edges, as shown in Fig. 9. The arrangement

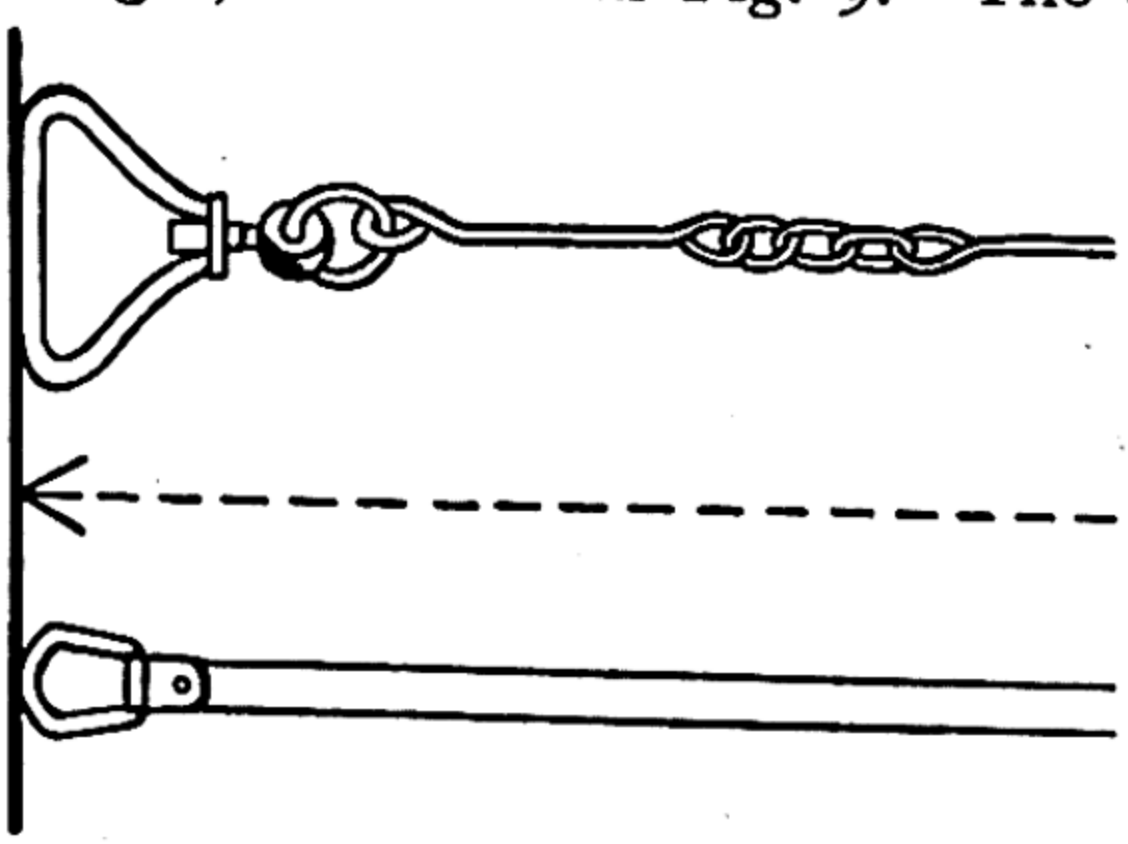


FIG. 9.—CHAIN AND TAPE.

of swivels, tabs, and points makes it possible for either end to be used as the beginning of the chain.

Distances may be recorded in either chains or links :

2 chains 41 links	=	2·41 chains	= 241 links
6 chains 5 links	=	6·05 chains	= 605 links
10 chains	=	10·00 chains	= 1,000 links
11 links	=	0·11 chains.	

A surveyor's tape has feet and inches marked on one side and links on the other. The brass loop at the beginning is part of the first foot.

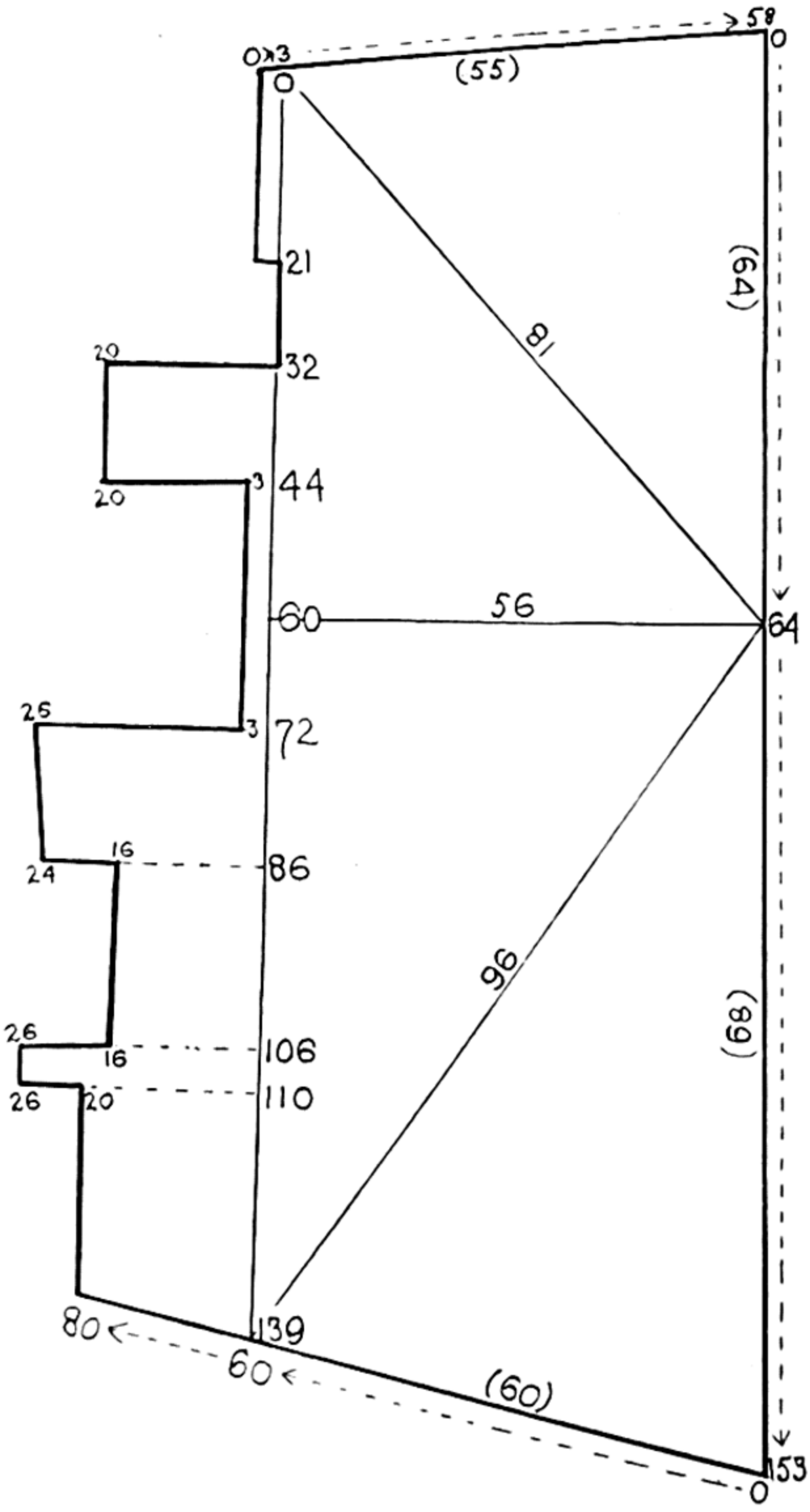


FIG. 10.—A LONDON SCHOOL PLAYGROUND MARKED OUT FOR SURVEYING.

(See Fig. 1.)

DRAWING THE PLAN OF THE PLAYGROUND

PRELIMINARY EXERCISES

C. 1. Copy the plan of the playground in Fig. 10, using a scale of 1 millimetre to a foot.

C. 2. Make a freehand plan of the playground of your school. Draw lines to mark off the irregular sides. Mark out offsets and triangles.

GROUP EXERCISES

1. Draw the same lines on the playground itself, measure them, and enter the numbers on the plan.

2. Draw the plan to scale.

STREET PLANS

The first piece of map has been chosen because most of the streets cut one another at right angles, and can therefore be easily drawn.

B. 3. Make a rough sketch of Mailand Road, like the one below the map, measure the distances on the map, and put them on your sketch. (Notice that all the measurements are made from one end.)

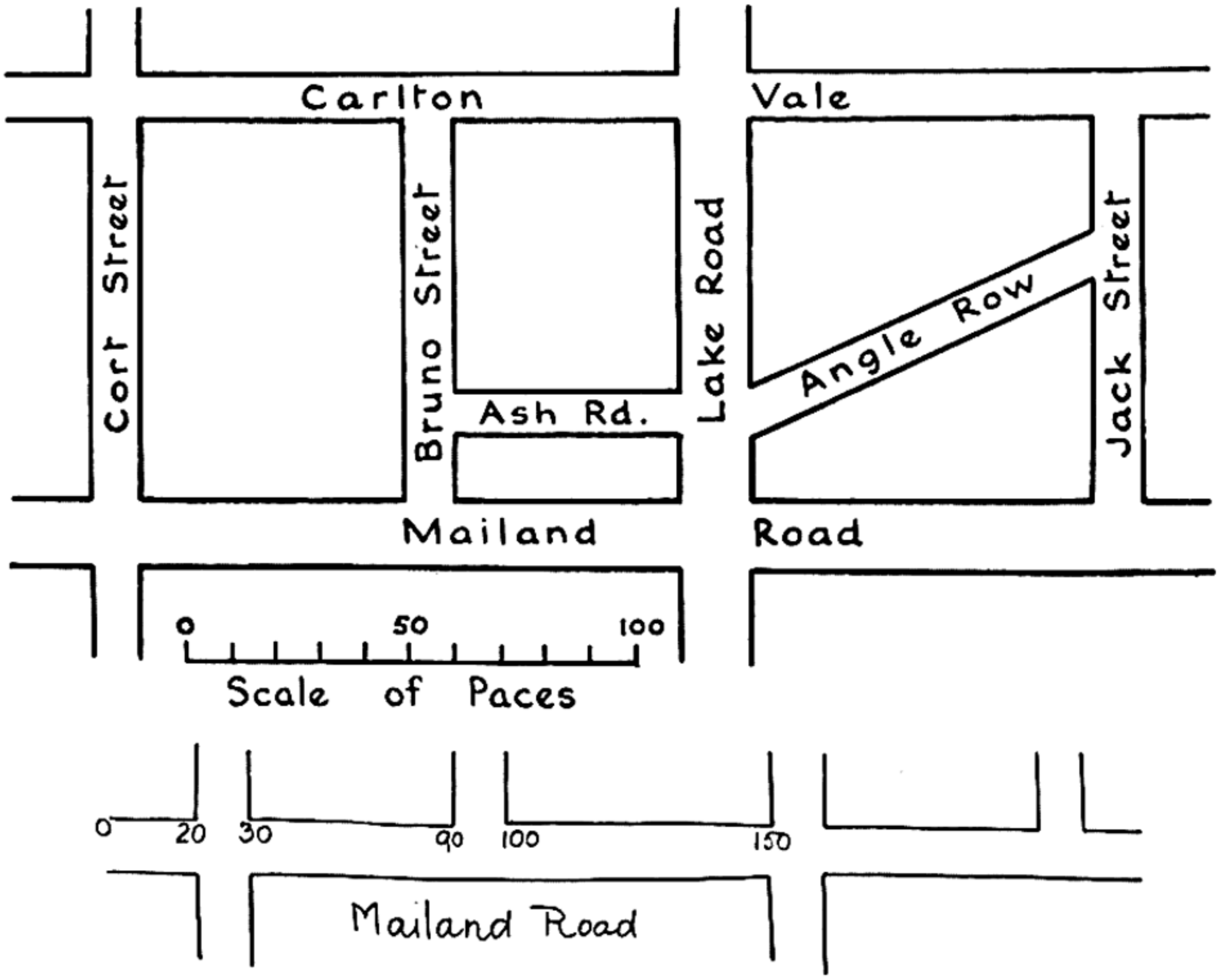


FIG. 11.

B. 4. Draw the street to the scale of 40 paces to an inch, using a ruler marked in tenths of an inch.

B. 5. Make a rough sketch of Lake Road, measure it, and draw it on the Mailand Road map to scale.

B. 6. Proceed similarly with Cort Street, Carlton Vale, and the rest until the map is completed. Add a scale.

In the second map (Fig. 12), the roads join at all angles.

C. 3. Make a rough map of Thorne Road, measure the distances on the map, and enter them on the sketch. (Let the measurements be from the farther end of the street in this case.)

C. 4. Draw the street to the scale of 800 feet to an inch. To get the correct direction of Fair Field Road, lay a piece of thin paper on

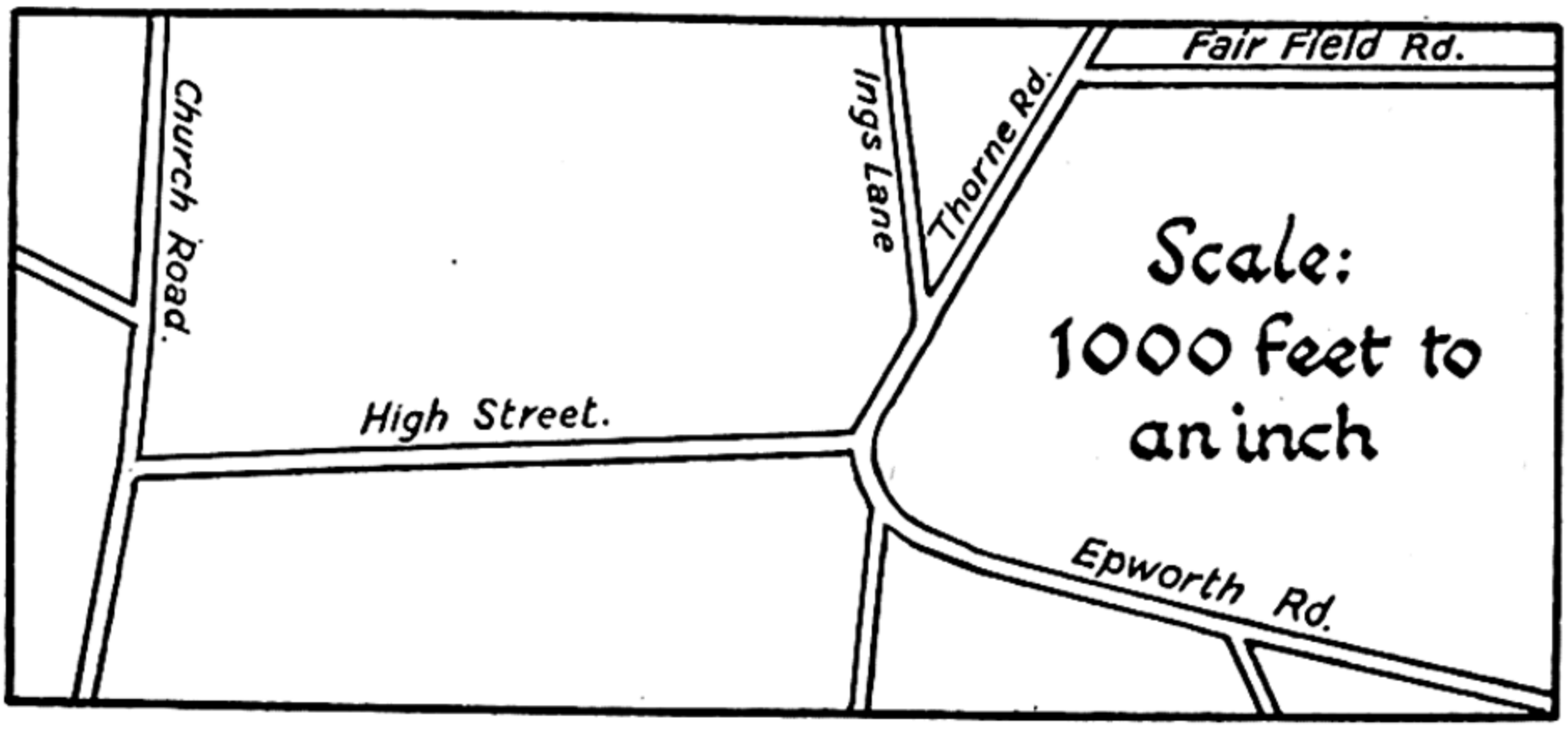


FIG. 12.

the map, mark over the angle between it and Thorne Road, and then trace it on your drawing.

Proceed similarly with the other roads. Add a scale.

The third plan is a very rough one, and on it are the measurements from which it is to be drawn. The numbers along the main street (High Street) refer to paces, and the degrees denote the angle at which the side streets branch off.

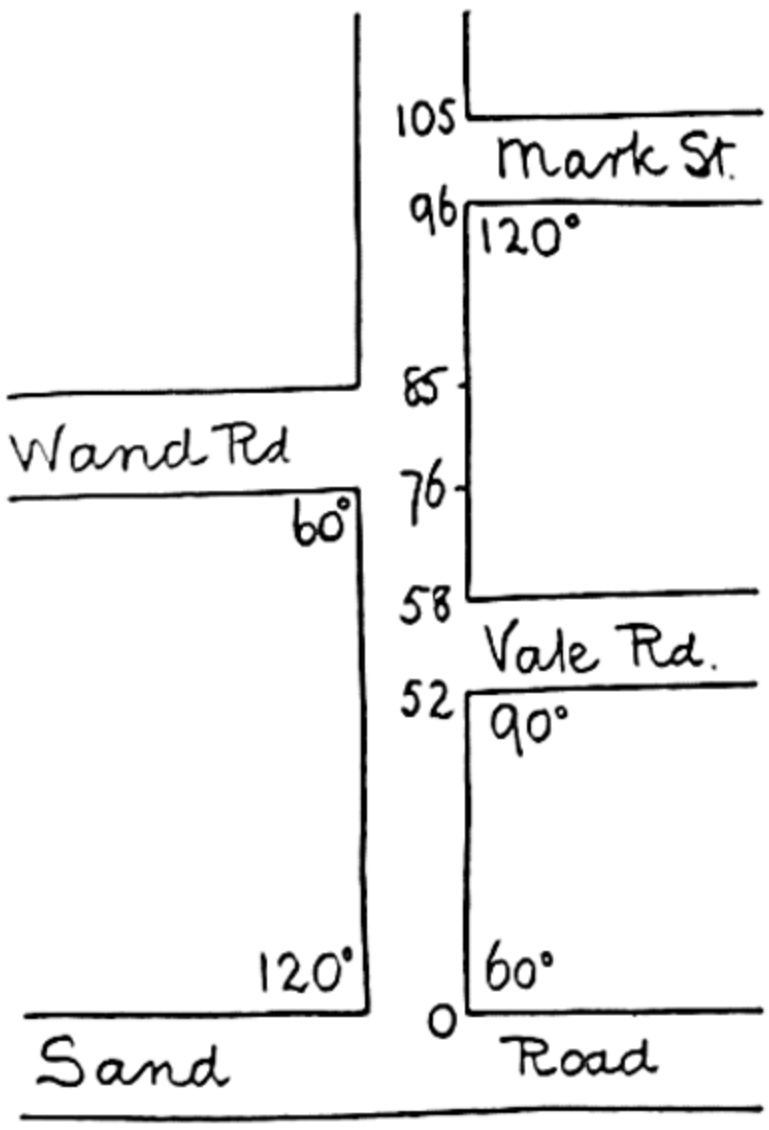


FIG. 13.—ROUGH PLAN OF SURVEY.

D. 1. Draw the plan of the streets on a scale of 40 paces to an inch. (High Street is 12 paces wide, Sand Road runs east and west. Only 30 paces of each side road need be drawn.)

THE LOCAL STREET MAP

B. 7. Draw the map of the streets in your neighbourhood, using your judgment as to the distances.

Measuring Distances.—Distances in the first case can be done by pacing. Stand with the feet together at the begin-

ning of the line to be measured. Start off with the right foot, and count one every time the left foot touches the ground.

Angles.—1. In a quiet neighbourhood the angle may be found as follows :

Lay a paper on a board at the corner of the streets, and on it place two rulers, crossing one another, one pointing along each street. Draw the angle between them with a pencil, cut it out, write on it the names of the two streets, and use it in drawing the plan.

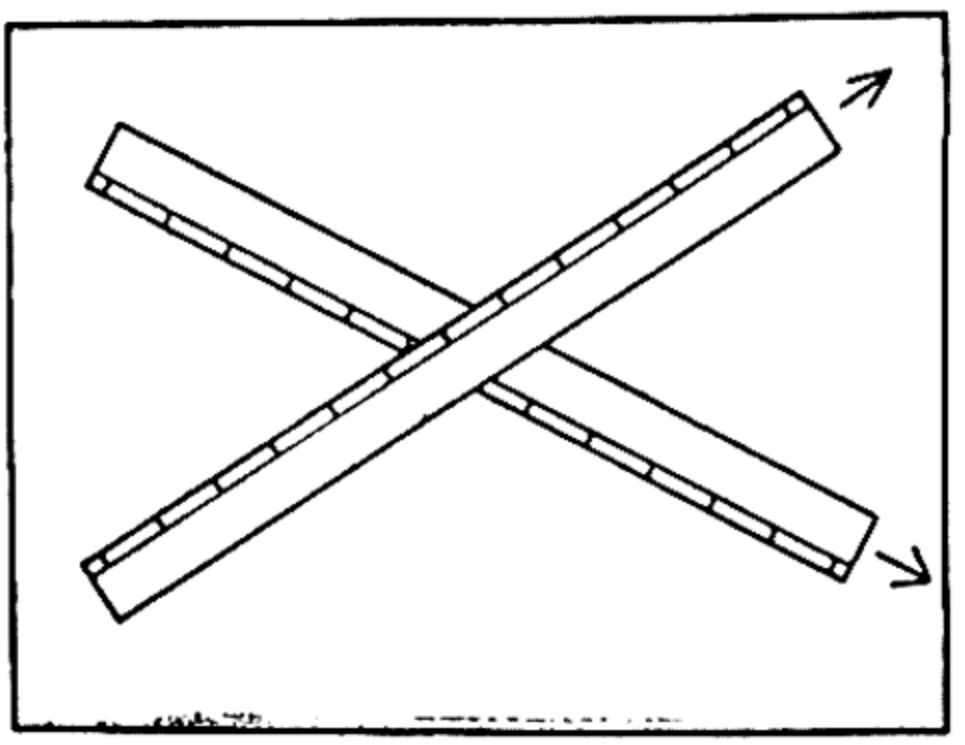


FIG. 14.—MEASURING THE ANGLE BETWEEN TWO STREETS.

2. *The Angle-meter* : This consists of a wooden disc, on which a pointer is pivoted in the middle (Fig. 15). The disc is marked off in degrees, and there are sighting pins at 0° and 180°. Two people are required to find the angle between two streets. The first holds the disc horizontally and sights across the pins along one street. The second moves the pointer until it sights along the other street. The angle is then read and recorded.

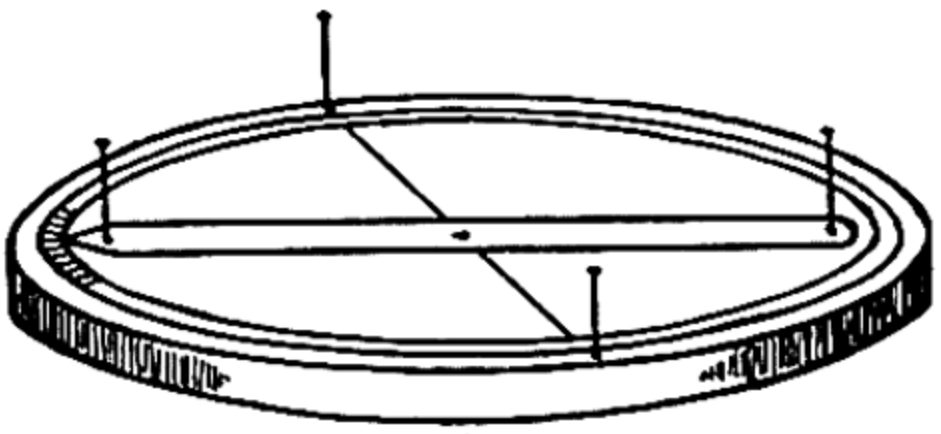


FIG. 15.—ANGLE-METER.

GROUP EXERCISE

Draw a plan of your neighbourhood to scale.

CHAINING A FIELD

In chaining a field the same method is employed as in making a plan of the playground. Since chalk marks, however, cannot be made on the ground, steel pins, or arrows, about

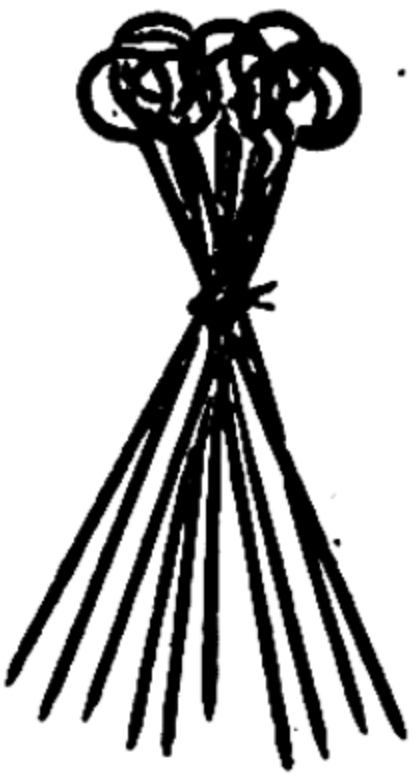
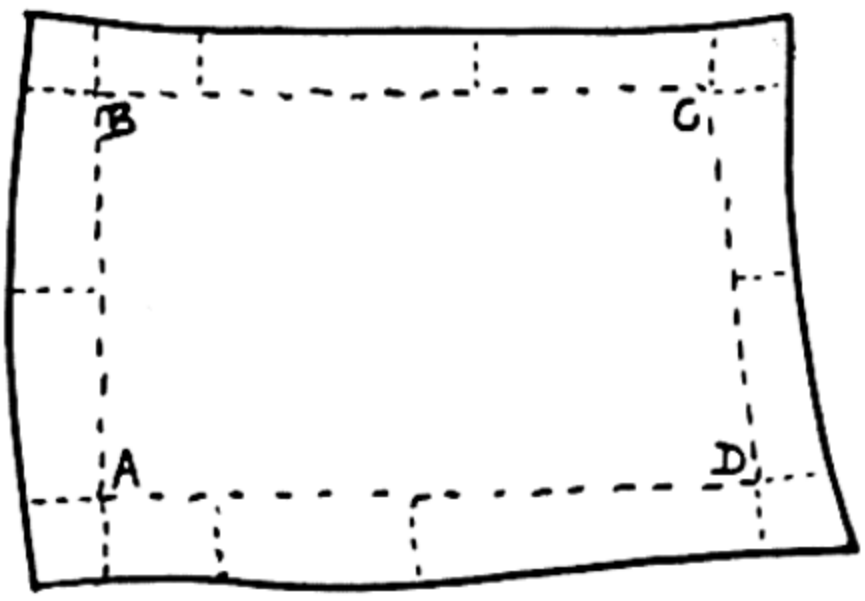
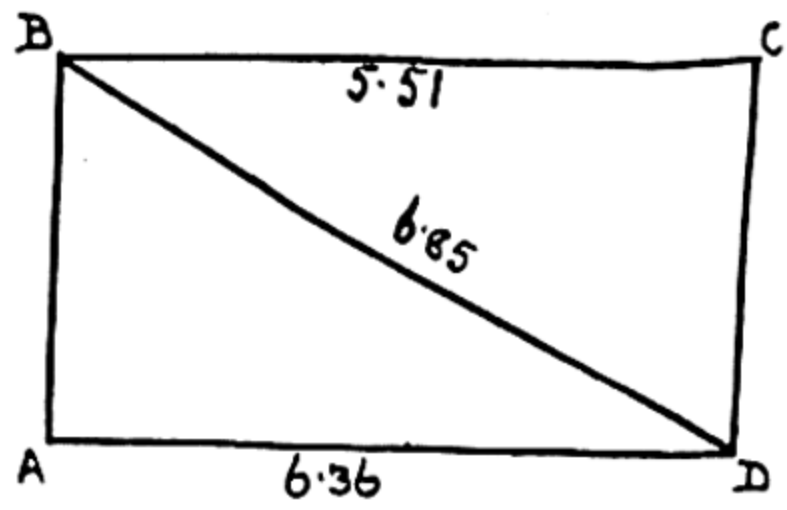


FIG. 16.—"ARROWS."

15 inches long, are used to mark where the end of the chain touches or where offsets occur. Another difference in work-



Scheme of measuring



The main figure

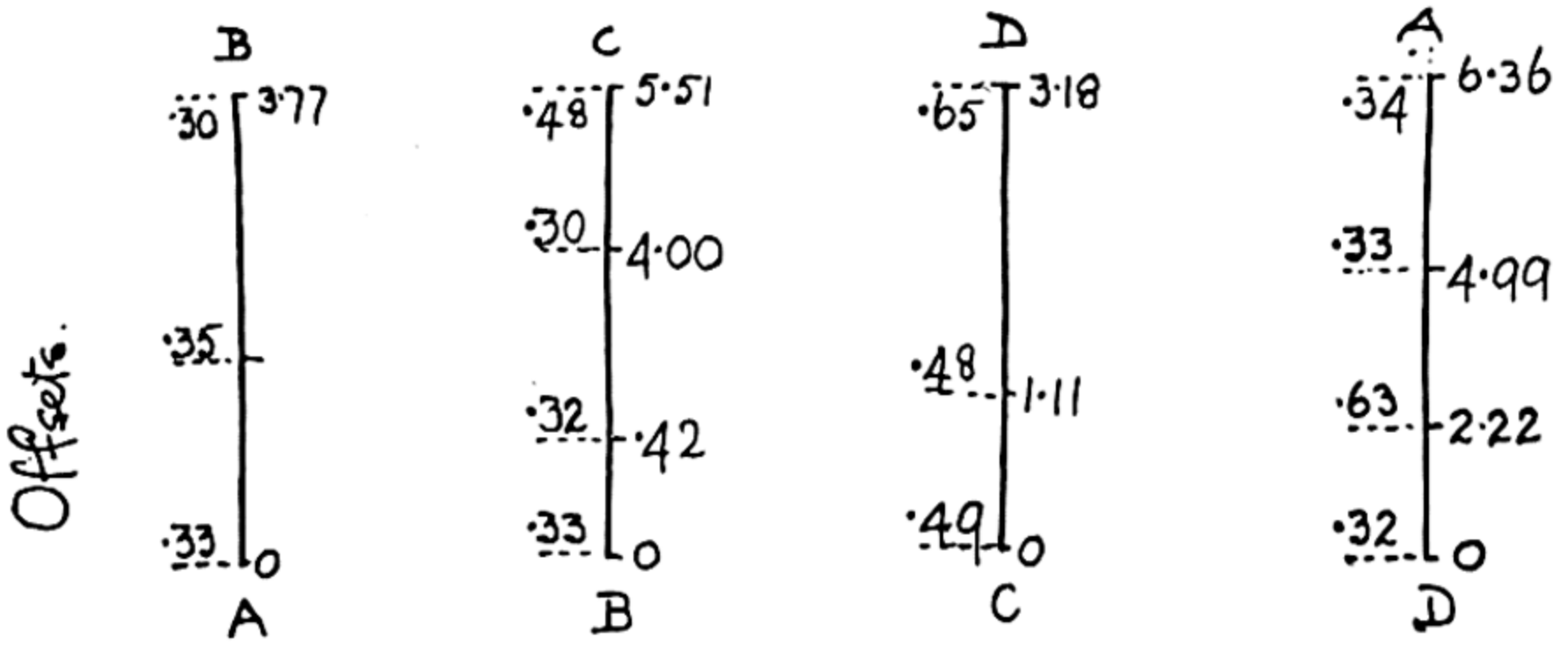


FIG. 17.—THE SURVEY OF A FIELD. MEASUREMENTS IN CHAINS.

ing comes from the fact that it is not always possible to measure along the extreme edge of the field because of ditches and bushes, and in consequence the rectangle (or other figure) may have offsets on all sides. The field in the exercise is taken from the map on page 131, and is the one numbered 158.

D. 2. Draw the plan of the field on a scale of 1 chain to an inch.

(On a large-scale plan further measurements in the corner at B would be necessary.)



FIG. 18.—OFFSETS.

THE COURSE OF A STREAM

The curved side of a field or the course of a stream can be surveyed by the offset method. The measurements in the exercise are for the section of the stream on page 131 between the two bridges.

C. 5. Draw the bank of the stream from the measurements in Fig. 18 on a scale of 200 links to an inch.

THE WIDTH OF A STREAM (THEORY)

The offset from C points to a stone X on the opposite bank of the stream. Y is marked so that the angle CYX is 45°. CY is 110 links. CX must also be 110 links. From C to the bank is 60 links. The stream is therefore 50 links wide.

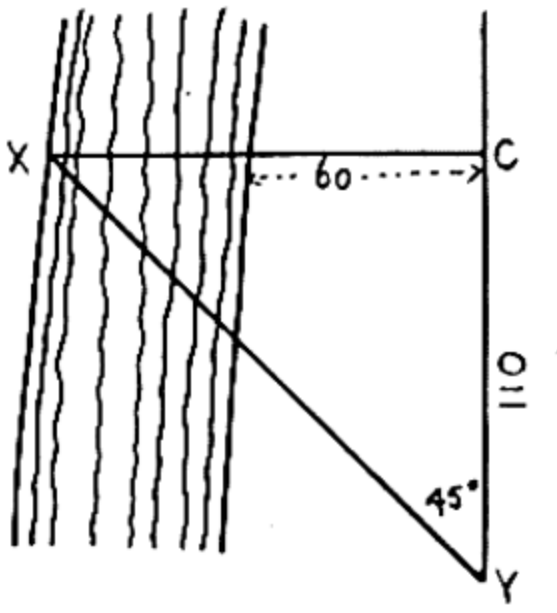


FIG. 19.—MEASURING THE WIDTH OF A STREAM.

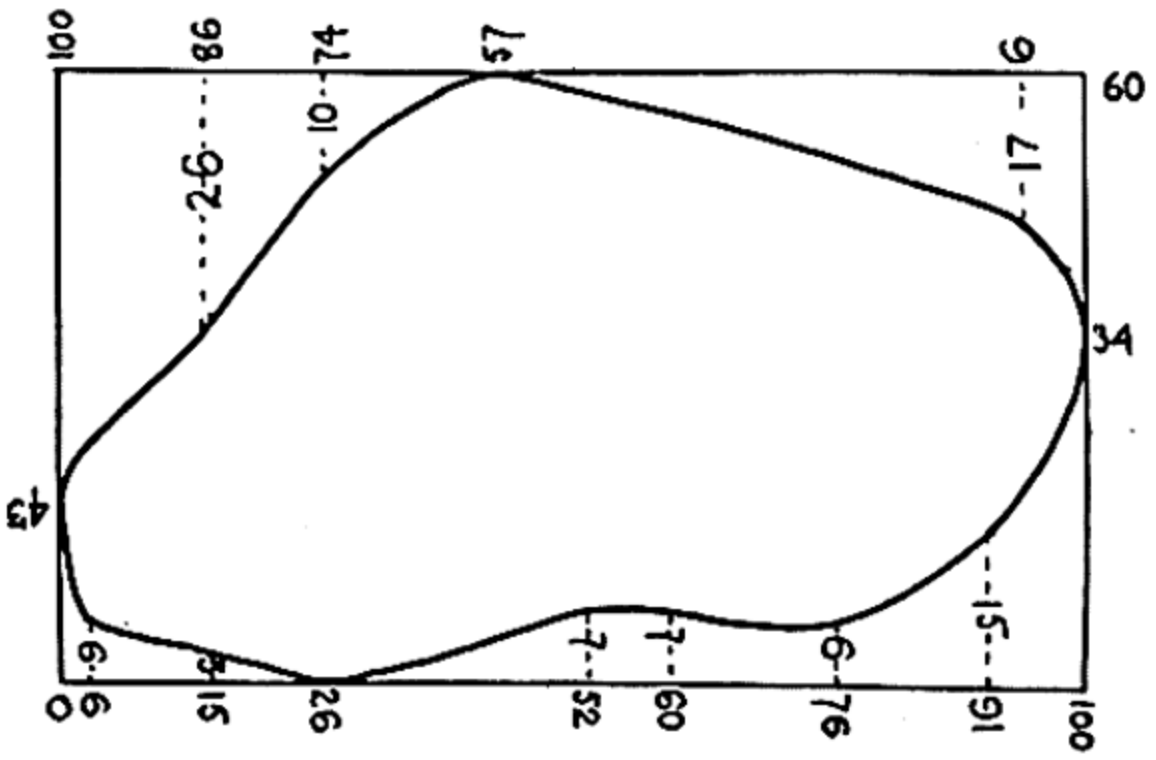


FIG. 20.—SURVEYING A POND.

THE PLAN OF A POND

A pond has been surveyed by marking a rectangle round it and taking offsets from its sides. The rectangle measures 100 links by 60 links.

D. 3. Draw the pond on a scale of 20 links to an inch.

QUESTIONS ON CHAPTER I

A. 1. Describe the surveying chain, its length, divisions, and tellers.
A. 2. In making a street plan where the streets cross one another at right angles, what are the three principal steps in the work?
B. 1. In making a plan where the streets cross at various angles, how would you determine the angles?
C. 1. Draw a rough plan of a playground with the lines you would mark out on the ground to help in drawing the plan to scale.
D. 1. Draw sketches to show how you would set to work:

(*a*) To make the plan of a field.
(*b*) To map a length of a stream.
(*c*) To find the outline of a pond.

Chapter Two

SCALES

SCALES ON PLANS

THE scale of a plan may be given in three ways :

1. By a line.
2. By a statement : Scale, 1 inch to a foot.

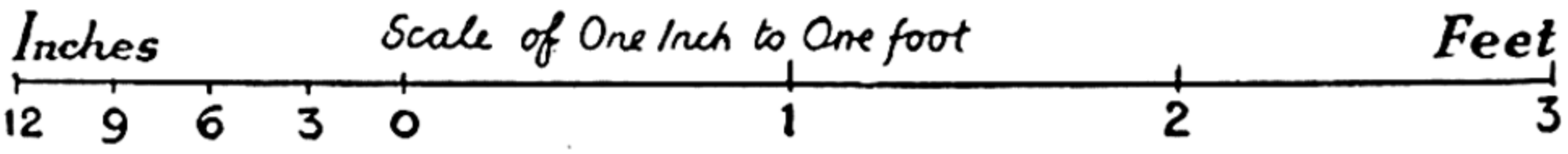


FIG. 21.

3. By a fraction : Scale of $\frac{1}{12}$, or 1 : 12.

 This is called the Representative Fraction, and is sometimes written R.F. $\frac{1}{12}$.

A. 1. Copy the scale of 1 inch to a foot.
A. 2. Draw a similar scale 1 inch to a yard to measure up to 5 yards.
B. 1. What is the Representative Fraction for a scale of :
 (*a*) $\frac{1}{4}$ inch to a foot ?
 (*b*) 1 inch to a yard ?
 (*c*) $1\frac{1}{2}$ inches to a yard ?
 (*d*) $\frac{3}{4}$ inch to a foot ?

SCALES ON MAPS

Scales on maps are given in the same three ways.

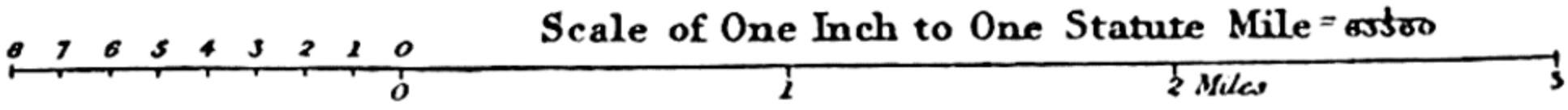


FIG. 22.

The " one inch to a mile " scale shows miles and furlongs, and has a R.F. of $\frac{1 \text{ inch}}{1 \text{ mile}}$ or $\frac{1}{63{,}360}$.

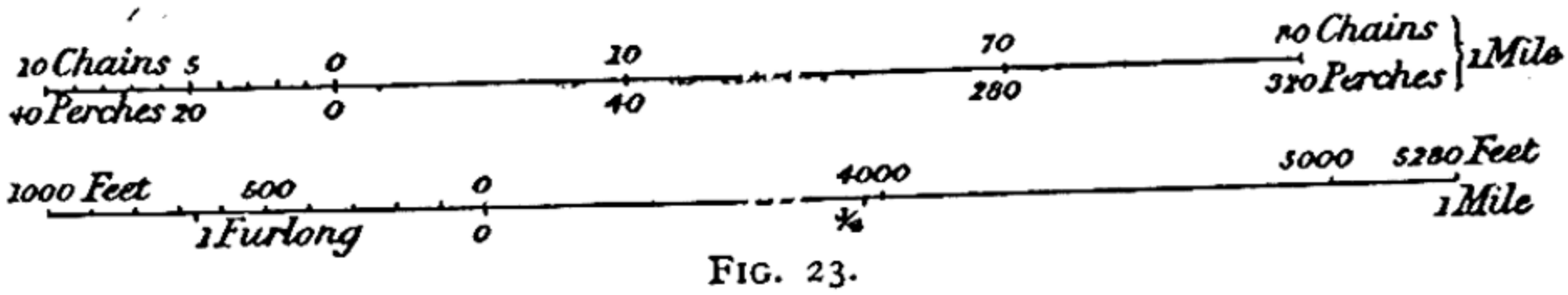


FIG. 23.

The " six-inch " map has a R.F. of :

$$\frac{6 \text{ inches}}{1 \text{ mile}} \text{ or } \frac{6}{63{,}360} \text{ or } \frac{1}{10{,}560}.$$

C. 1. What is the Representative Fraction for a scale of :

(*a*) $\frac{1}{4}$ inch to a mile ?
(*b*) $\frac{1}{2}$ inch to a mile ?
(*c*) 10 inches to a mile ?
(*d*) 1 foot to a mile ?
(*e*) 25 inches to a mile (in round numbers) ?
(*f*) 50 inches to a mile (in round numbers) ?

THE ACCURACY OF SCALES ON MAPS

On maps of small areas, such as England and Wales, the scales may be considered true in all parts of the map and in all directions, but on maps of the continents the scales given are true in most cases only near the centre of the map.

Measure the distance between Aberdeen and Archangel on as many maps as you can and compare the results.

ENGLISH AND METRIC SCALES

In countries using the metric system the Representative Fraction becomes the " Title " : the " hundred-thousandth " or the " eighty-thousandth " (1 : 100,000 or 1 : 80,000).

The following examples show how to convert one scale into another.

1. Express the scale of 1 inch to a mile as so many centimetres to a kilometre :

$$\text{R.F.} = \frac{1 \text{ inch}}{1 \text{ mile}} = \frac{1}{63{,}360}.$$

$$\frac{1 \text{ kilometre}}{63{,}360} = \frac{100{,}000 \text{ c.m.}}{63{,}360} = 1{\cdot}57 \text{ cm.}$$

Scale required is 1·57 cm. to 1 km.

2. Express the scale of 1 centimetre to a kilometre in terms of inches to a mile :

$$\text{R.F.} = \frac{1 \text{ cm.}}{1 \text{ km.}} = \frac{1}{100{,}000}.$$

$$\frac{1 \text{ mile}}{100{,}000} = \frac{63{,}360 \text{ inches}}{100{,}000} = \cdot 6336.$$

The scale required is ·63 inch to a mile.

D. 1. Convert the following scales :

(*a*) 6 inches to a mile to so many centimetres to a kilometre.
(*b*) 10 miles to an inch to the number of kilometres to a centimetre.
(*c*) 10 kilometres to a centimetre to miles per inch.

THE SCALE OF ONE-MILLIONTH

1 : 1,000,000 or 1/M.

The scale of 1/M is a useful and easy one to remember, since a million inches are approximately 16 miles (1,000,000 ÷ 63,360 = 15·79).

If 1/M be taken as 16 miles to an inch, what do the following fractions represent :

(*a*) 1 : 500,000 ; 1 : 250,000 ; 1 : 62,500 ?
(*b*) 1 : 2,500,000 ; 1 : 25,000,000 ; 1 : 50,000,000 ?

Exercises in Drawing Scales

B. 2. Draw a scale of 8 miles to an inch to measure up to 40 miles (add R.F.).
B. 3. Draw a scale of 40 miles to an inch to measure up to 100 miles (add R.F.).
B. 4. Draw a scale of 400 miles to an inch to measure up to 1,000 miles (add R.F.).
C. 2. Express both in terms of inches to a mile and in centimetres to a kilometre the scales $\frac{1}{10000}$, $\frac{1}{80000}$, $\frac{1}{100000}$.
C. 3. Draw a scale of 1/M to measure up to 100 miles.
C. 4. Draw a scale of 1/M to measure up to 100 kilometres.

Chapter Three

DIRECTION

FINDING THE CARDINAL POINTS

NORTH by the compass. Lay the compass on the floor and turn it until the needle points a little to the west of north, as in the illustration. Then stretch a string along the N.–S. line of the compass card and use it as a guide for drawing the line. There is always a danger that water pipes and radiators may cause the needle to point in the wrong direction. In one school the boilers in the basement made it point due east.

North by the pole star. On a clear evening stand so that the pole star appears to touch the edge of a building. Mark the place where you are standing and draw a line or lay a stick from there in the direction of the pole star.

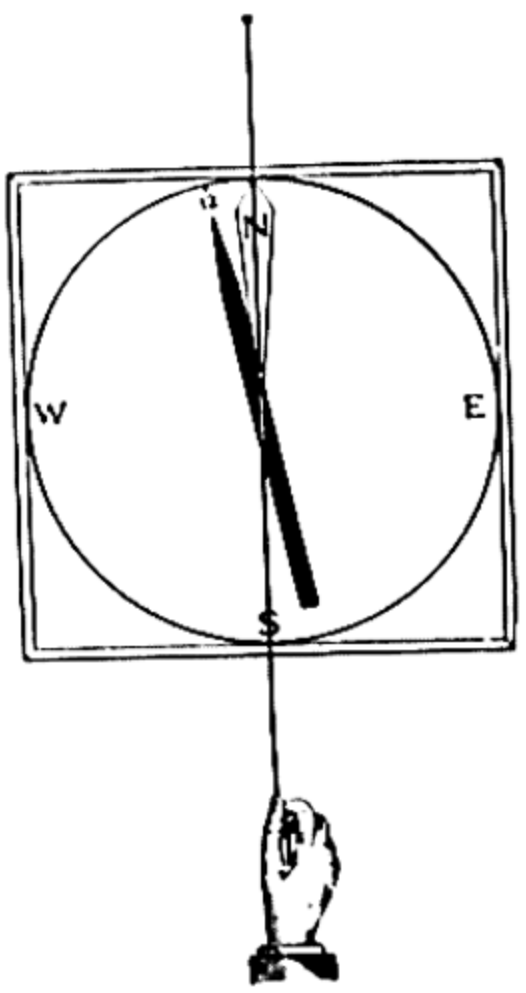


FIG. 24.—DRAWING A N.–S. LINE WITH THE COMPASS.

East and West. At the equinoxes (March 21st and September 24th) the sun rises due east and sets due west.

FINDING SOUTH WITH A WATCH

If we used watches with the twenty-four hours marked on them, we should hold the watch so that the small hand pointed to the sun and then look in the direction shown by XII for the

south. As our watch dials are divided into twelve hours, we must halve the distance between the small hand and the XII.

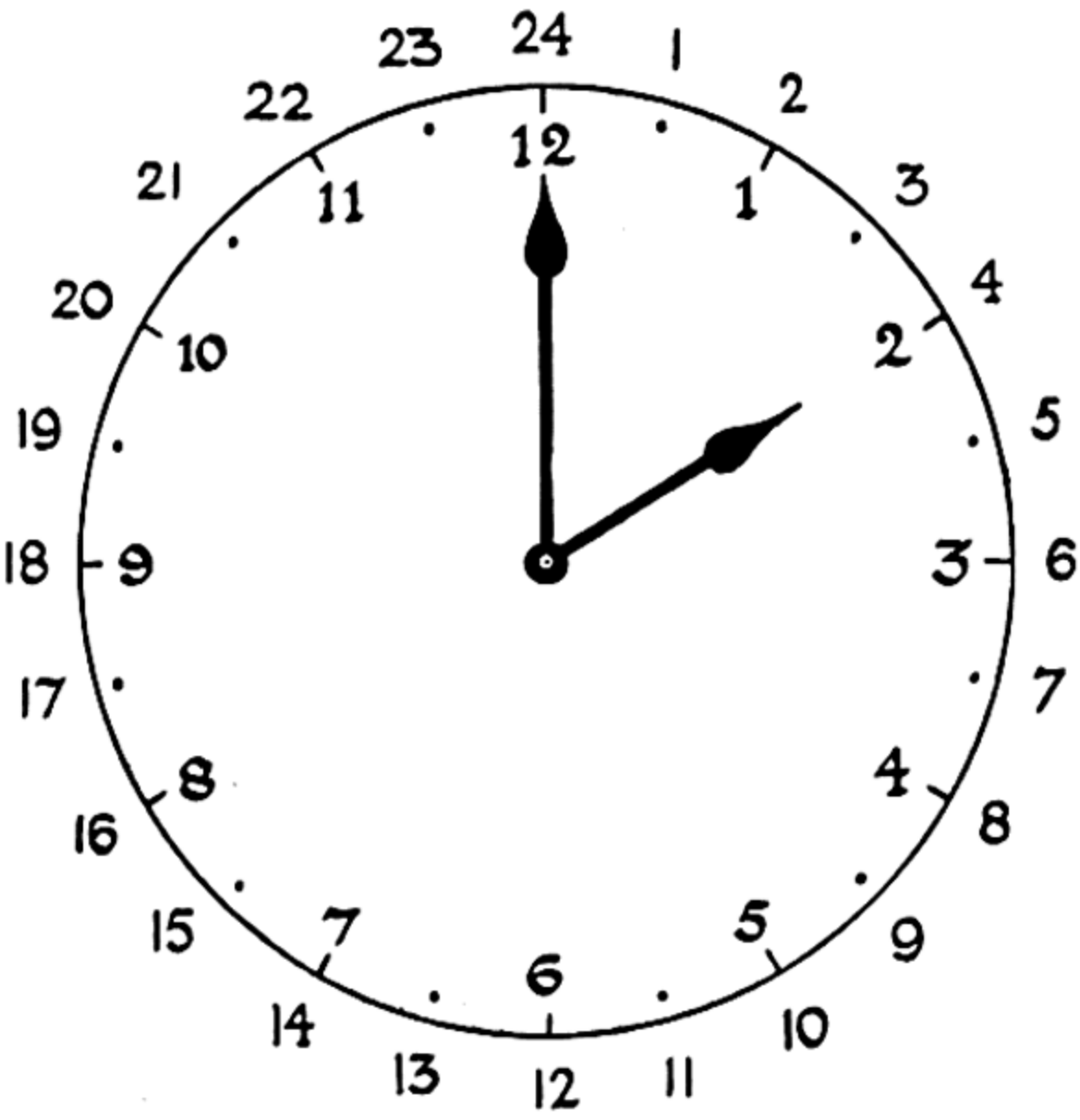


FIG. 25.—TWELVE- AND TWENTY-FOUR-HOUR DIAL.

A sundial, like the one in Fig. 90, could be used and would give a more exact result than the watch.

A GUIDE-POST FOR A HEMISPHERE

The map inside the cover is drawn in such a way as to show us the direction of various parts of the world as seen from England. Thus if a man living in Birmingham faces due east, he is looking across Germany, the Black Sea, and India to Ceylon. Or, to put it another way, suppose that we had a cannon in England that would send a shell just over five thousand miles. If we turned the weapon due east and fired it, the shell would pass over Germany, the Black Sea, and India and land in Ceylon.

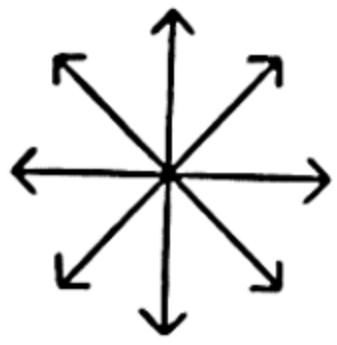


FIG. 26.

There are marks on the borders of the map to help in finding E., S.E., etc.

Turn the map so that its lower edge is towards the south. Lay a ruler across it east and west and passing through your own part of Britain. Face westward, and you are looking towards the Atlantic and the West Indies, and beyond

that across Central America to the Pacific, those being the parts through which the ruler passes.

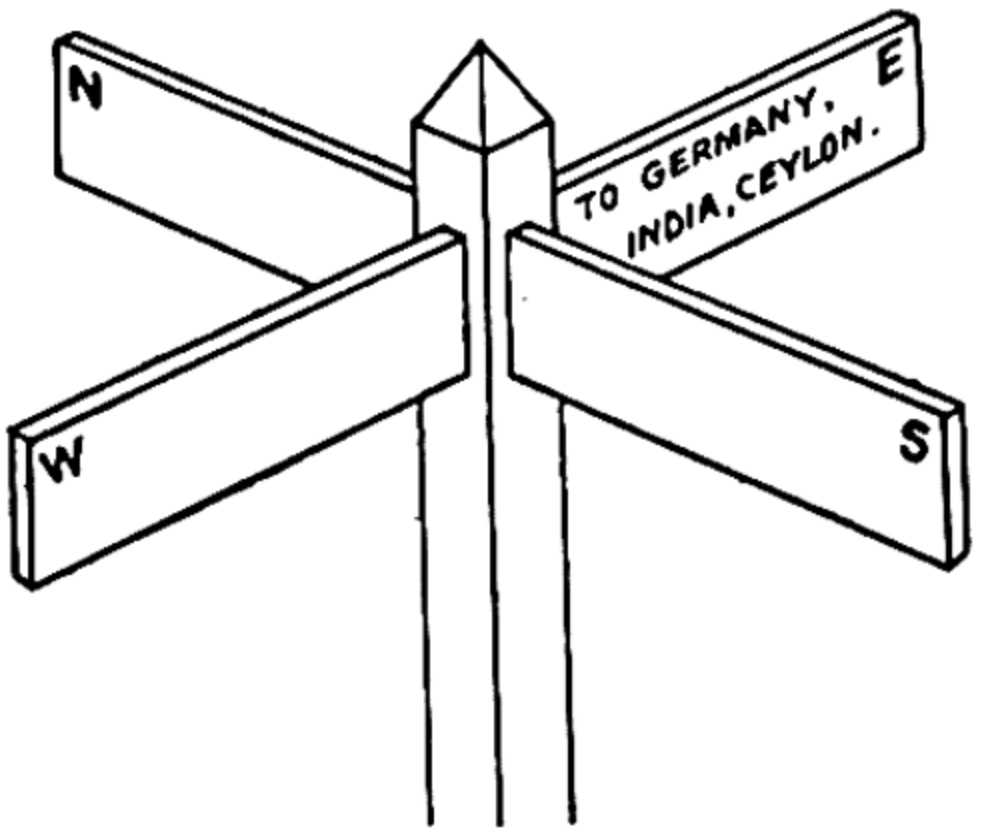


FIG. 27.—A GUIDE-POST FOR A HEMISPHERE.

THINGS TO DO

B. 3. Cut a slit in the top of a stick and insert a strip of card so as to make a guide-post with two arms. On the one write "To Germany" and on the other "To the West Indies *via* the Atlantic....."

B. 4. Add two other arms with their names. Fix the stick with the arms pointing in the right directions.

C. 1. Make a dial to show the direction of the following wireless stations: Berlin, Dublin, Madrid, Moscow, Oslo, Paris, Pittsburgh, U.S.A., Reykjavik, Riga, Rome, Stavanger, Stockholm.

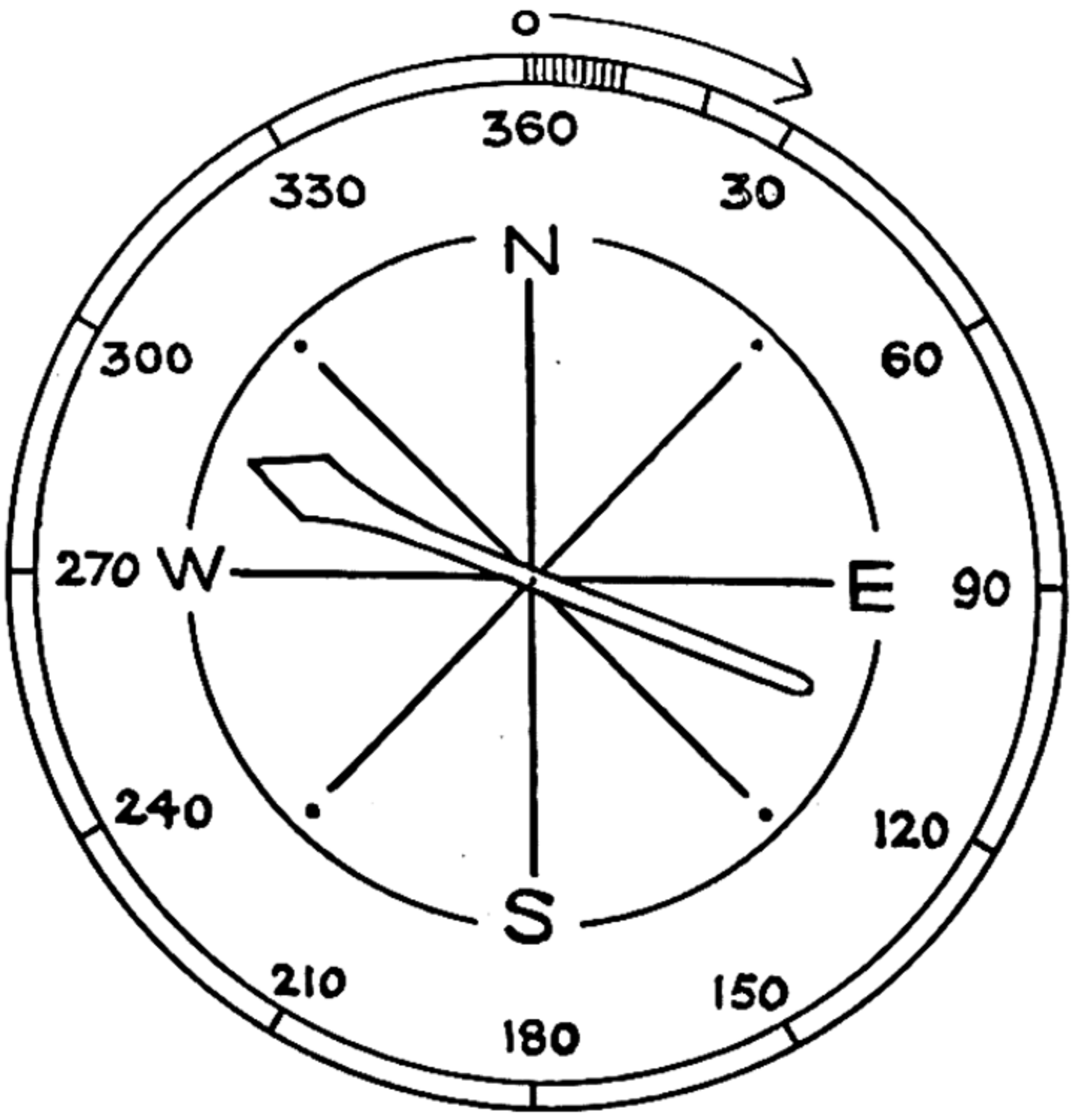


FIG. 28.—DIRECTION AND DEGREES.

DIRECTION AND DEGREES

The compass with 32 points comes to us from the days of sailing ships.

In navigation to-day, and in giving the direction of upper air currents for aircraft, angular measure is employed, the

degrees being numbered clockwise from the North, which is zero. The compass that is used for surveying is numbered similarly.

A. 3. Draw the four cardinal points with the angles shown in Fig. 28.

B. 5. Draw eight points of the compass and add their angular equivalents (N., 0°, N.E. 45°, etc.).

C. 2. At one station on February 22nd, 1931, the directions of the winds at various heights were as follows :

Surface. . .	215°	4,000 feet . .	275°
2,000 feet . .	280°	11,000 feet . .	305°

Find approximately from Fig. 28 what the directions were in terms of the compass points.

Make a drawing showing the directions in which the four winds blew.

THE VARIATION OF THE COMPASS NEEDLE

In the year 1580 the compass needle pointed 11° east of north in London ; in 1652 it was due north, and by 1815 had moved 24½° to the west. The amount has since been diminishing until in 1934 it is 11° west. This departure from the true north is called the " variation." In crossing the Atlantic from Glasgow to Quebec, the direction of the needle changes continuously, reaching as far as north-west in the middle of the journey.

At the mouth of the River Mackenzie the north end of the compass needle points S.E.

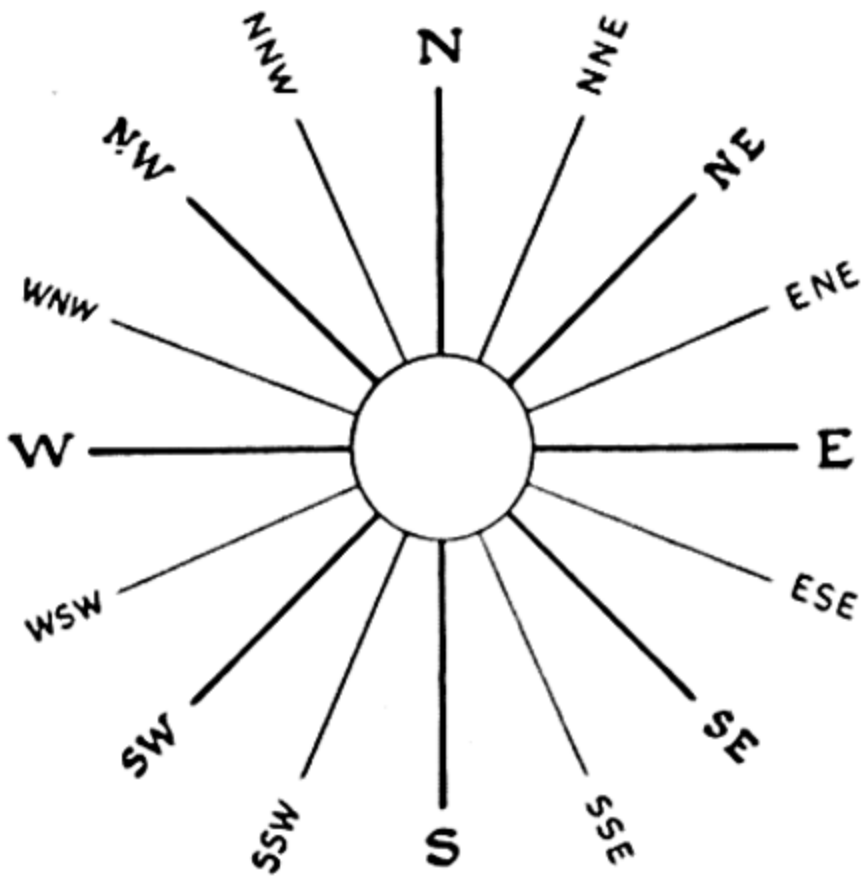


FIG. 29.—SIXTEEN POINTS OF THE COMPASS.

REVISION EXERCISES

A. 1. Make a drawing showing eight points of the compass.

A. 2. Make a similar drawing with sixteen points.

B. 1. Find from the atlas map the name of the town to the north of yours, then one that is N.E., and so on for each of the eight points. Write them out as in Fig. 30, which was made for Reading. Turn your drawing

so that the northern arm points to the north and the directions of all the other towns can be seen.

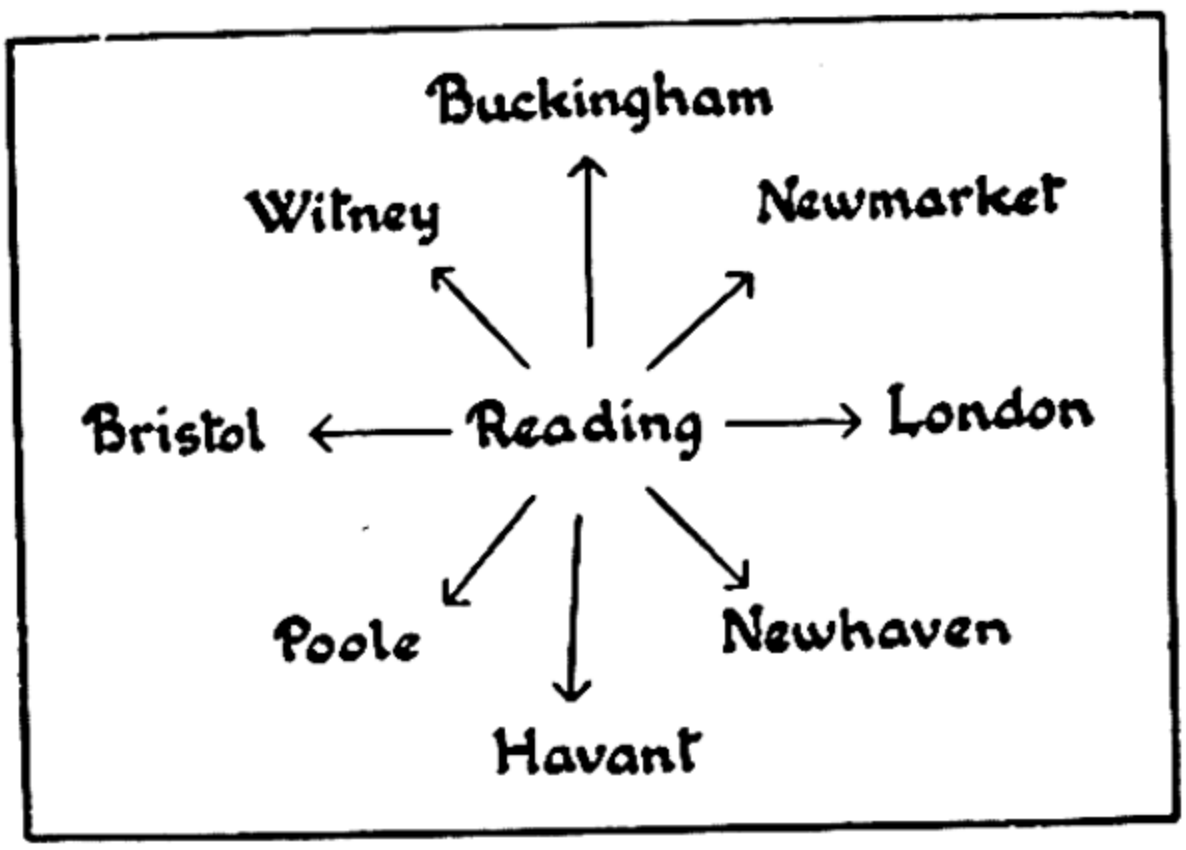


FIG. 30.—A POINTER FOR READING.

QUESTIONS ON CHAPTER THREE

A. 1. In which side of the sky does the sun rise? When is it due south?

B. 1. In which direction does the sun rise (1) on Midsummer day, (2) on Midwinter day, (3) on March 21st?

A. 2. How can the north be found by the stars?

B. 2. How would you draw a north-south line?

B. 3. In what ways can the south be found?

C. 1. What difficulties are there in drawing a north-south line with a compass?

Chapter Four

RELIEF

WHEN we speak of the "relief" of a country we mean the character of its surface, whether it is a plain or whether it is mountainous. If the country is a level plain, like some parts of the east of England, the drawing of a map is not a very difficult task because the land as we look at it appears almost as flat as the paper we are working on. But when we come to a hilly region, or mountainous country like Wales, we are faced with the problem of how to draw the mountains, valleys, and plains, all on the one flat sheet of paper.

Many ways have been tried, but none is quite satisfactory when used by itself, and we therefore employ several methods on the one map. On an ordinary atlas map, for instance, we find four: (1) contour lines, (2) various shades of green and brown (green for the lowlands and brown for the high parts), (3) hill shading, and (4) numbers that tell us the heights of the peaks in feet.

CONTOUR LINES

A contour line is a "level" line. If a man walking along the side of a hill takes care to go neither up nor down, his path is a contour line. At the seaside he follows such a line when he walks along the edge of the water. To get away from the edge, he must either go *up* the beach or *down* into the sea itself.

ISLAND CONTOURS

In the sections that follow a number of "islands" are used because they make it easier to understand the meaning of

contour lines than is possible with an ordinary map. If the lowlands of England and Wales were flooded the hills would stand above the water as islands and some of them would correspond fairly closely to those that appear here, though their slopes, perhaps, would not be quite so steep.

ISLAND I.

1. This island is occupied by two hills, a higher and a lower, which are connected at the narrowest part by a "saddle."

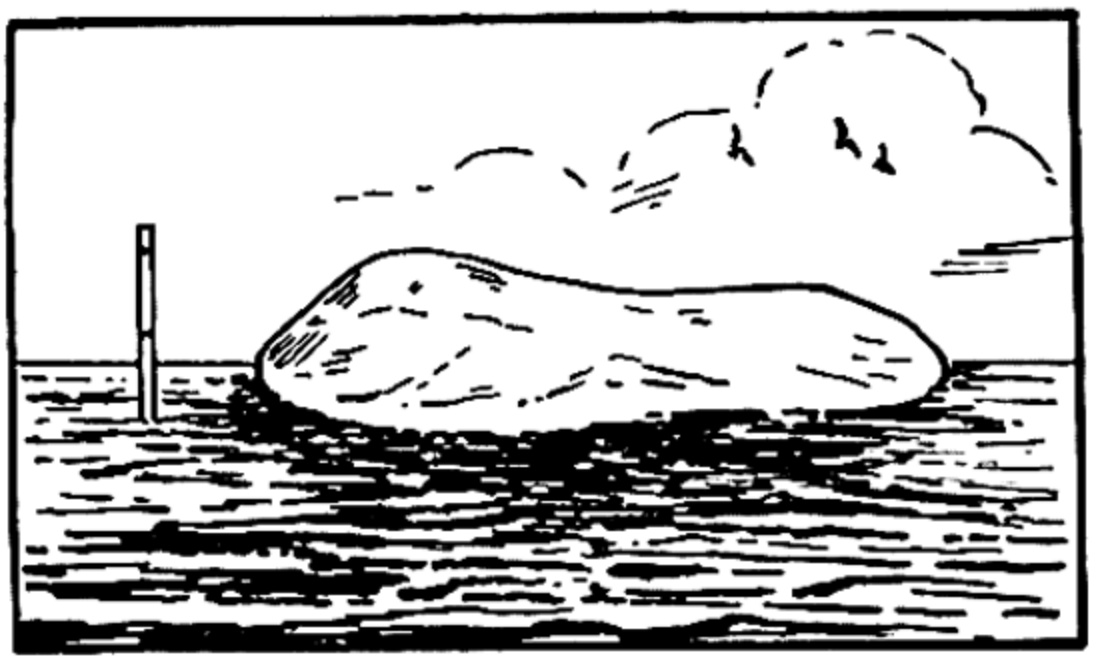


FIG. 31.

2. If the level of the water rose a hundred feet the island would be smaller, though its shape would remain about the same.

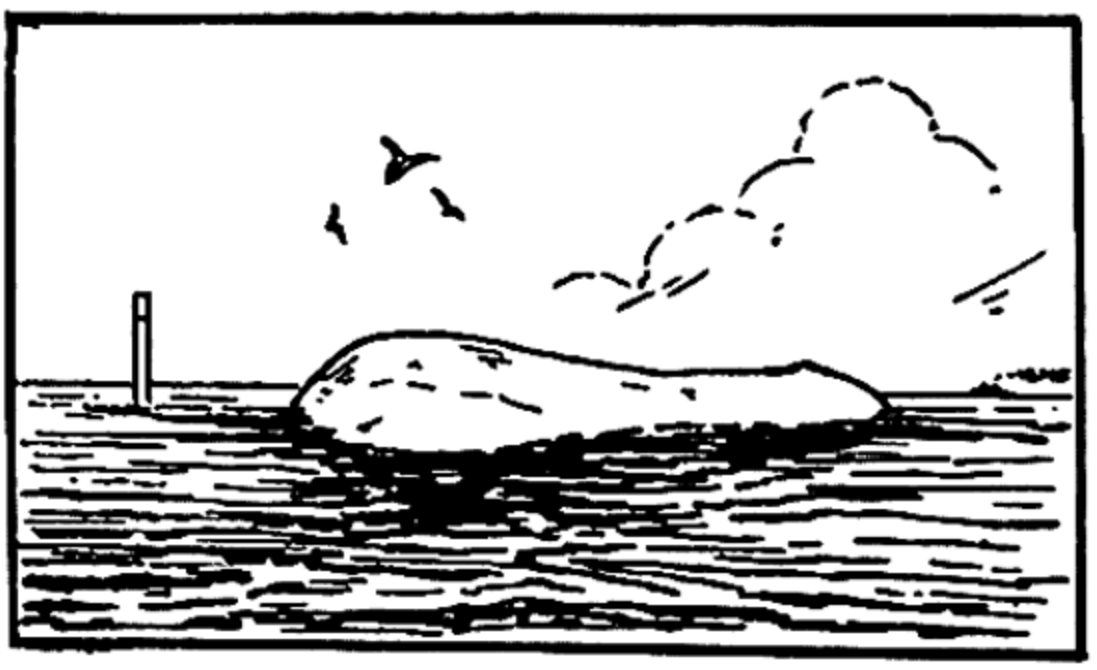


FIG. 32.

3. If the level rose another hundred feet the saddle would be covered and the two hills converted into islands.

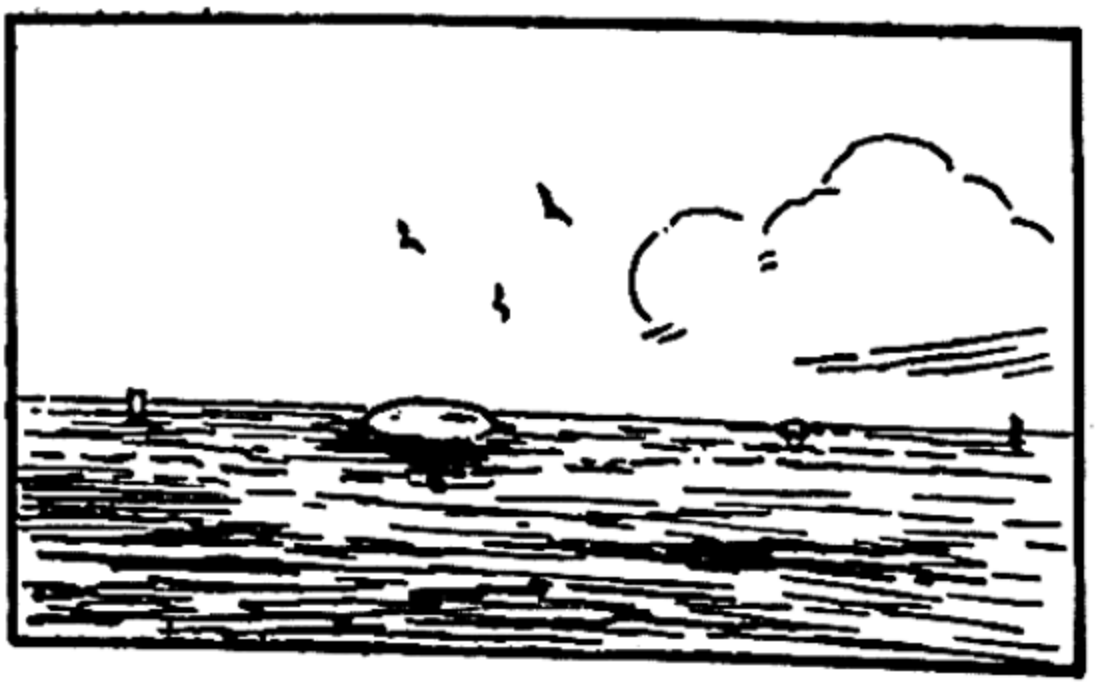


FIG. 33.

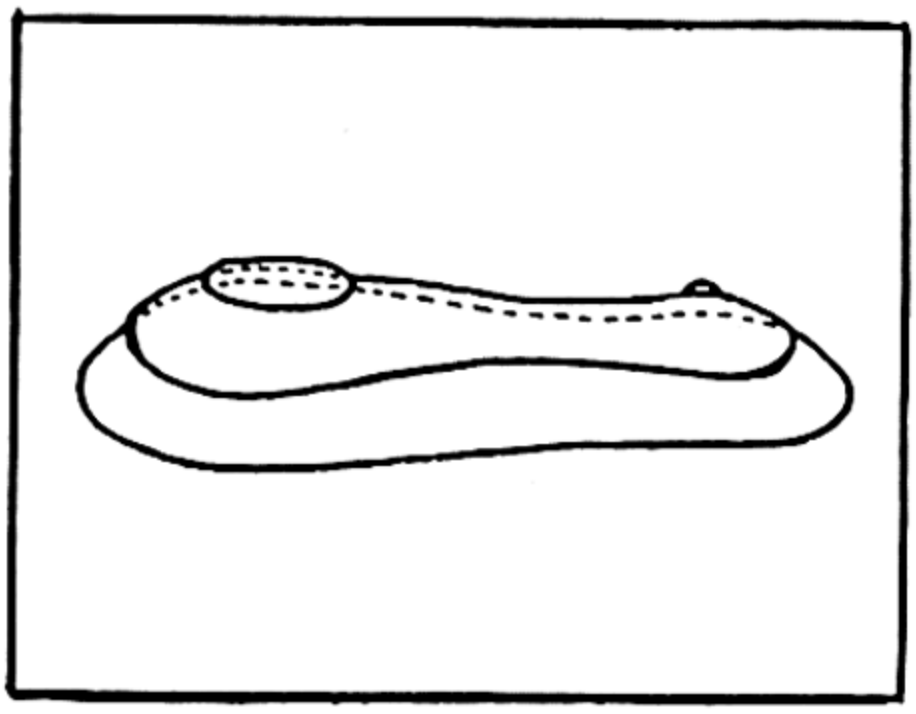


FIG. 34.

4. Here are the three coast-lines in position. It is easy to imagine from these what the shape of the island is.

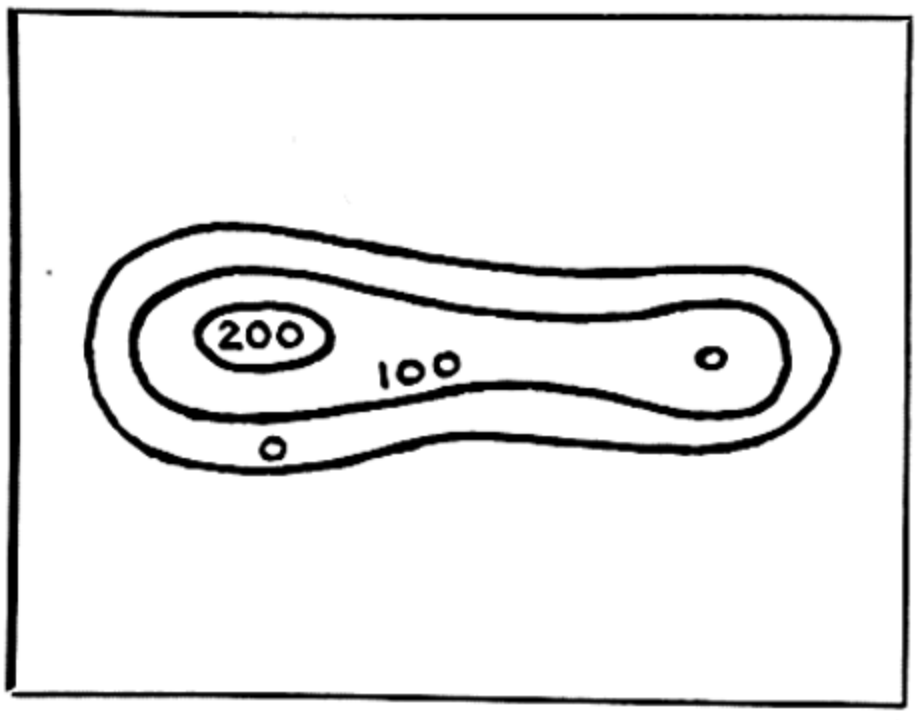


FIG. 35.

5. This is the contour map of the island.

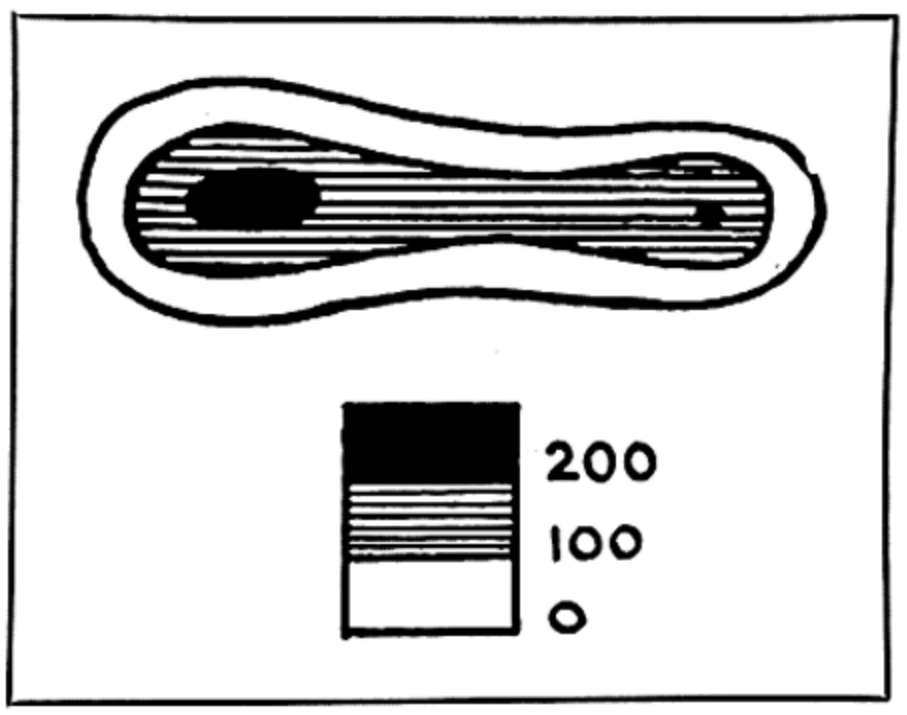


FIG. 36.

6. And this is the same map shaded for height.

A. 1. Copy the map and shade it for height.

ISLAND II.

1. This island is elliptical in shape and has very regular slopes. The lines show where the seashore would be if the water rose first one hundred feet and then two hundred feet.

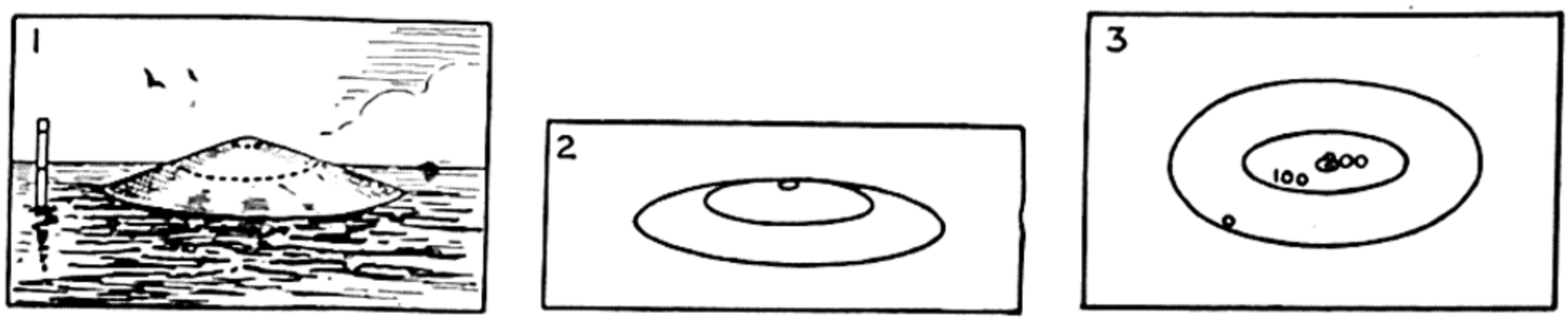


FIG. 37.

2. The shore lines in position.
3. The contour map of the island.

A. 2. Measure the distances between the contours on opposite sides of the island. (Notice that in the picture both sides of the island are regular and that the slopes are the same.)
A. 3. Copy the picture of the island, adding the higher shore lines.
A. 4. Copy the map and shade it according to height.

Island III.

1. Island III, like II, is elliptical in shape, but the slope on the left is much steeper than the one on the right.

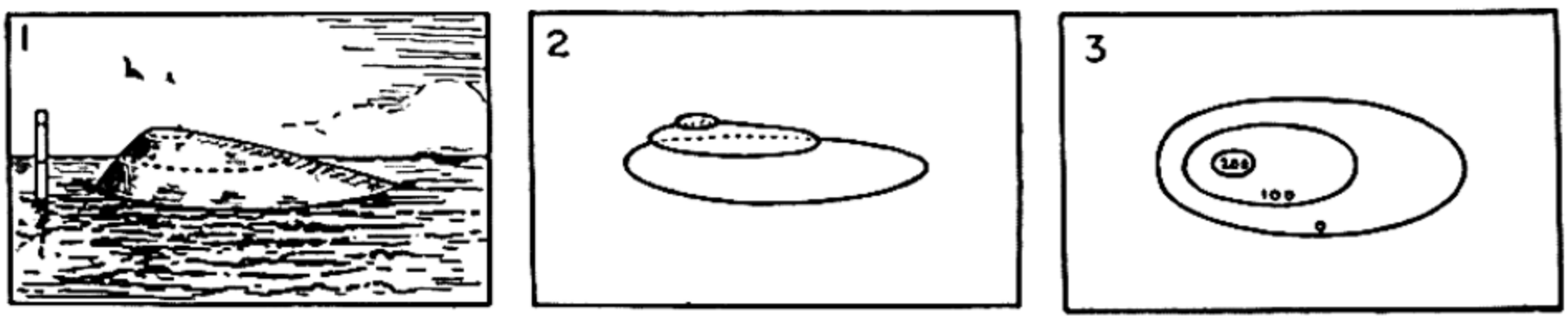


Fig. 38.

2. The contour lines in position.
3. The contour map.

A. 5. Make a sketch of the island.
A. 6. Measure the distances between the contour lines on the left side and compare them with the distances on the right side.
A. 7. Copy the map and shade it for height.

Island IV.

Island IV is elliptical, but its slopes get steeper and steeper as we go from the shore inland.

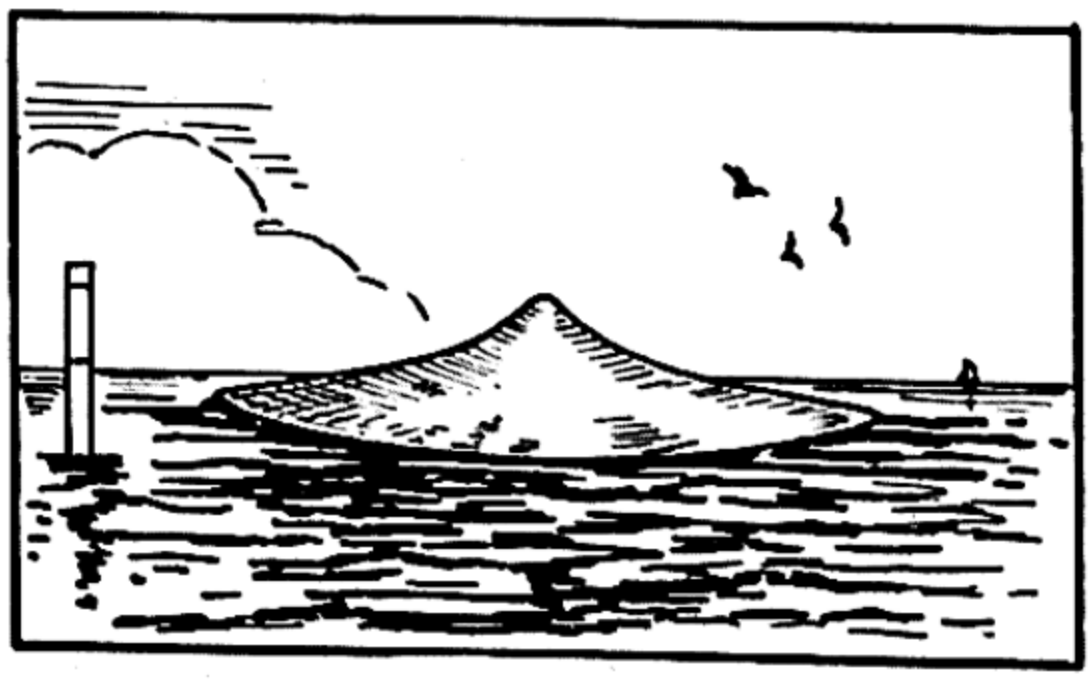


Fig. 39.

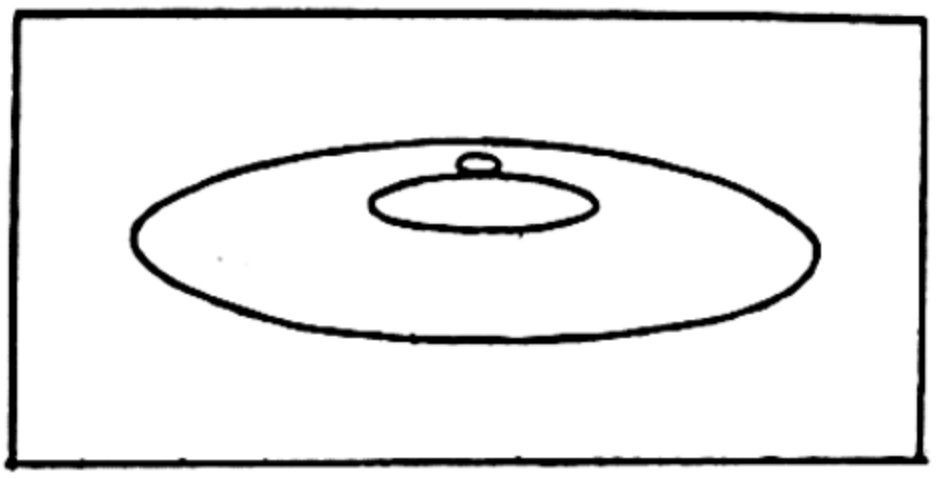


FIG. 40.

The contours in position.

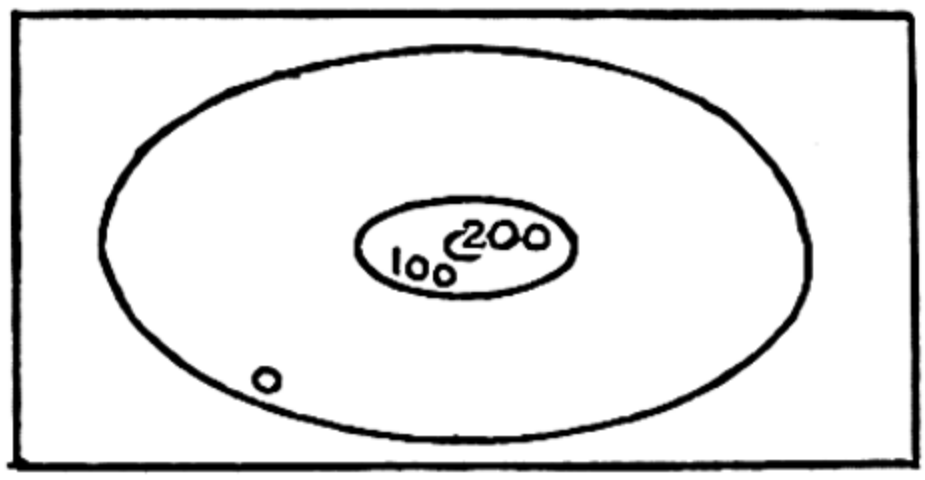


FIG. 41.

The map.

A. 8. Compare the distance on the map between the shore line and the 100-feet line, with the distance between the 100- and 200-feet lines.

A. 9. What relation do you notice between the closeness of the contours and the degree of slope as seen in the picture ?

A. 10. Make a sketch of the island.

A. 11. Draw the map of Island IV and shade it according to height.

A. 12. Draw an island that has rather less difference between the slopes of the higher and lower portions than there is in Island IV.

ISLAND V.

1. Island V, like the others, is elliptical in shape. Its slopes vary from the shore inland, but not in the same way as in the preceding example.

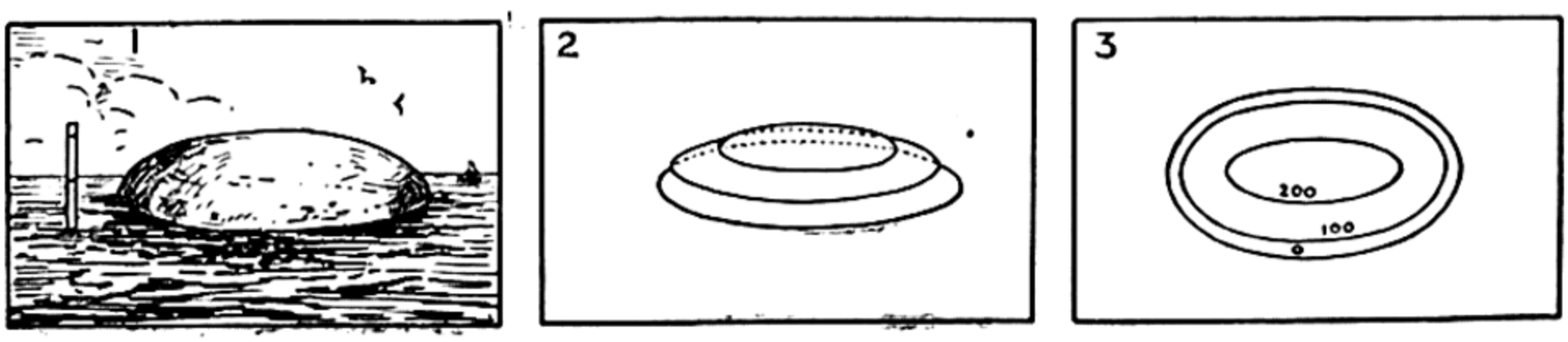


FIG. 42.

2. The contours in position.

3. The map.

A. 13. Describe the slopes of the island going from the sea inland to the middle.

B. 1. Compare and contrast the slopes of this island with those of II, III, and IV.

B. 2. Draw the contour map of the island and shade it for height.

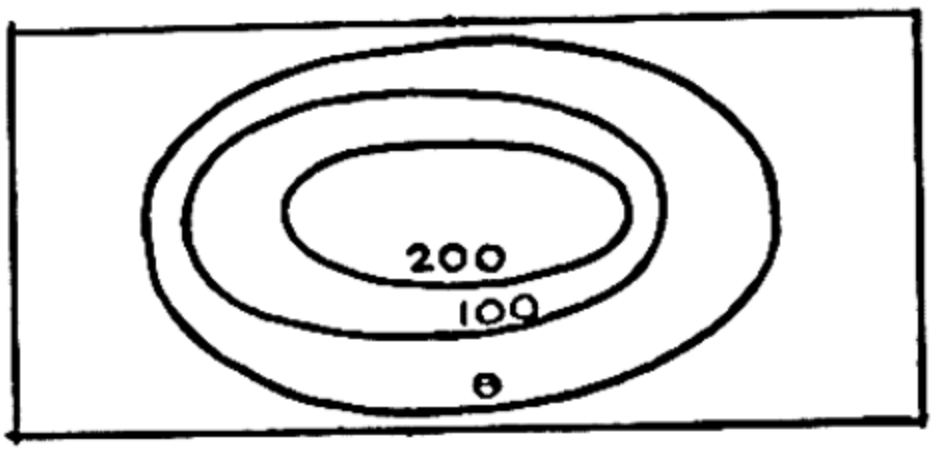


FIG. 43.

ISLAND VI.

C. 1. Describe the slopes of Island VI from the map and make a sketch to show the rise and fall of the surface from side to side.

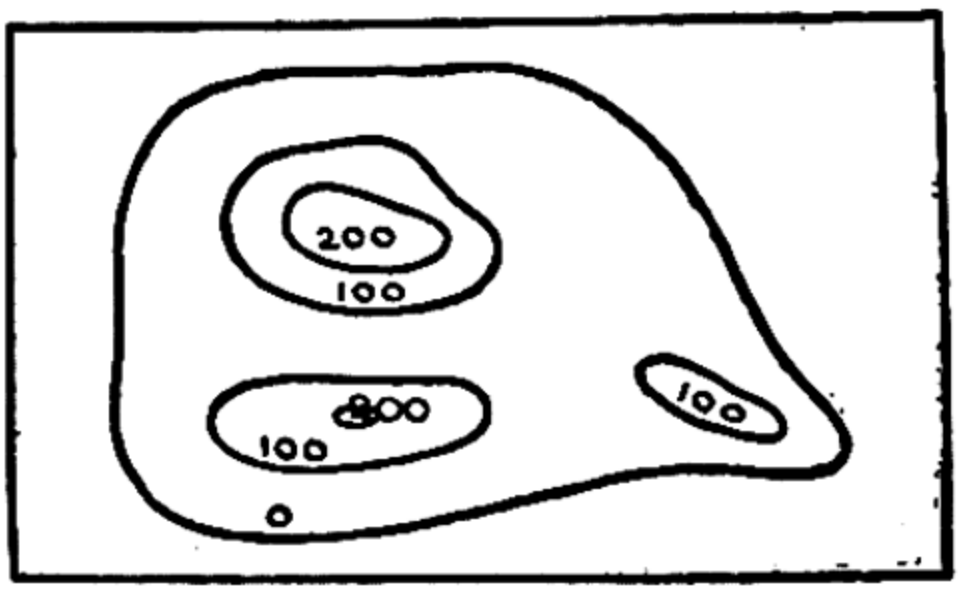


FIG. 44.

ISLAND VII.

C. 2. Describe the island from the map.

ISLAND VIII.

DRAWING A SECTION

To check our ideas about the relief of a piece of country it is sometimes of advantage to draw a section across it. We

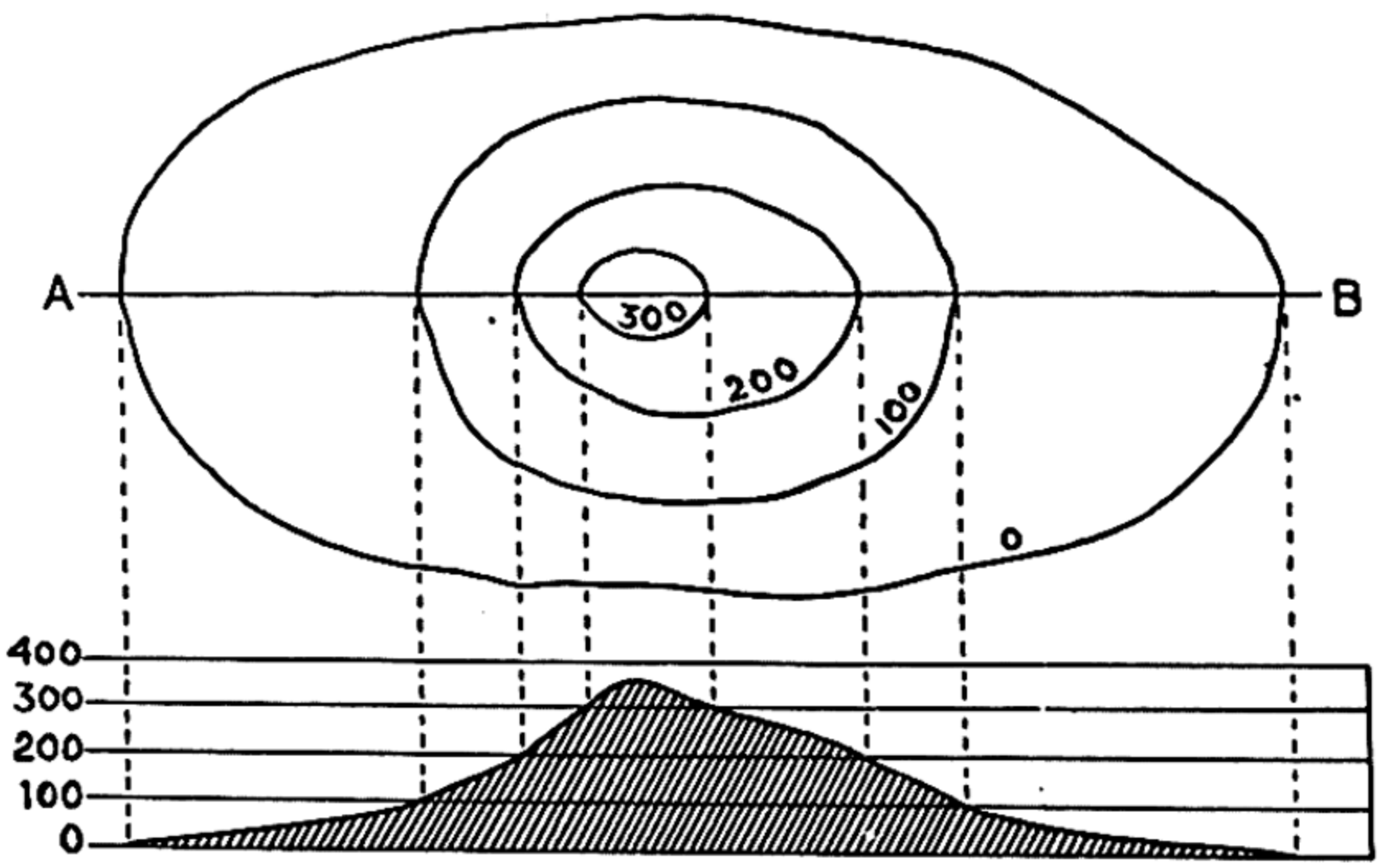


FIG. 45.—DRAWING A SECTION.

can find the character of the slopes of Island VIII, for instance, by imagining it cut in two along the line AB.

The map is drawn to a scale of 500 feet to an inch.

Draw a series of horizontal lines an eighth of an inch apart and number them 100 feet, 200 feet, 300 feet, 400 feet.

From the points where the line AB cuts the 300-feet contour drop perpendiculars to the 300-feet line below.

Drop perpendiculars similarly from where it cuts the other contours.

Join up the points and shade the section.

C. 3. Copy the map and draw a section along AB.

C. 4. Copy the map and draw a section along AB, shading both map and section for height.

In the following exercises consider the length of all the islands to be 600 feet and the width 500 feet.

C. 5. Copy the map of Island II ; draw a line AB through its length ; draw a section along AB and shade it.

C. 6. Copy the map of Island III. Draw a section through it. Shade map and section.

C. 7. Copy Islands VI and I and draw sections through them, shading both maps and sections.

VALLEY CONTOURS

In the first picture is a small stream valley running down to a lake.

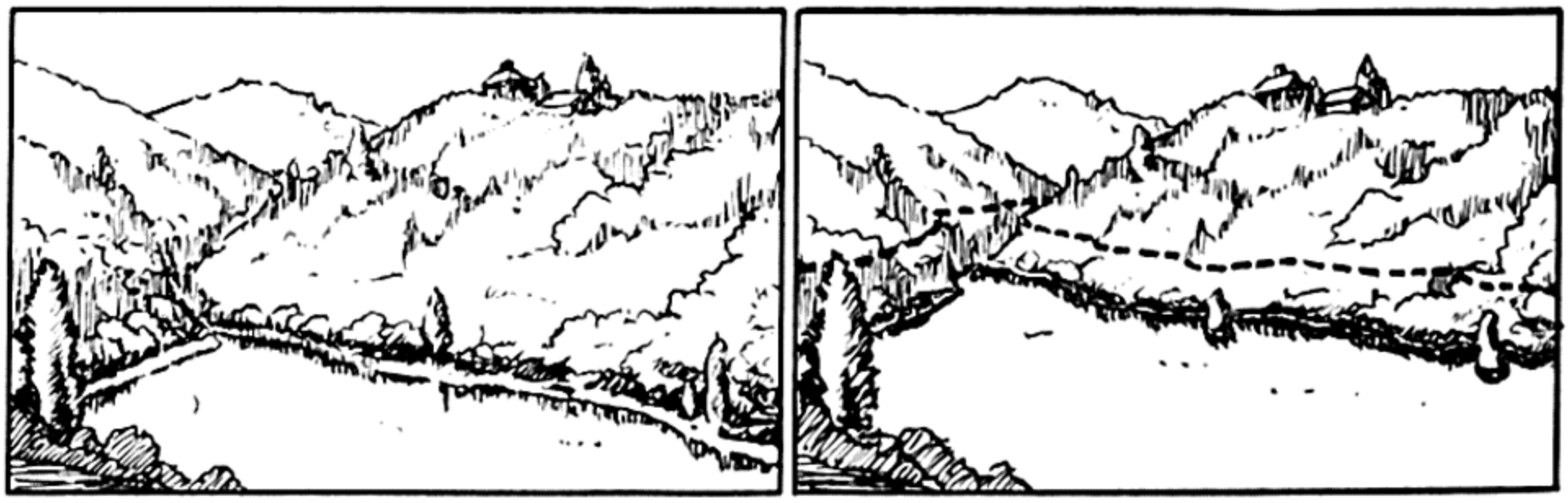


FIG. 46.—A RISING LAKE.

In the second picture the rise of the lake level is seen in the half-drowned trees.

In the second picture the water has risen twenty feet above its former level and a line has been drawn to show where it would come to if it rose another twenty feet.

The map gives the three contour lines.

Look at the first picture and try to imagine the course of the 20-feet line. Then look at the second and try to imagine the appearance of the edge of the lake when the water reaches the 40-feet line.

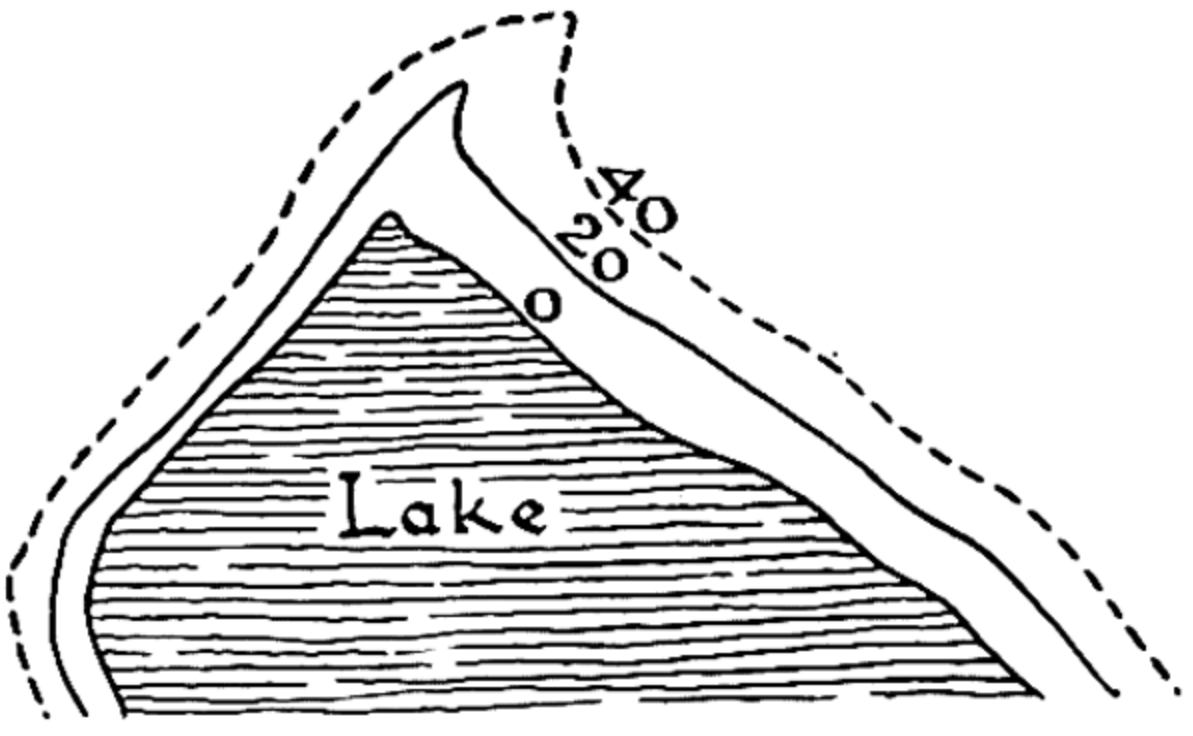


FIG. 47.—CONTOUR MAP OF THE LAKE IN FIG. 46.

B. 3. Copy the map and shade it for height.

For the understanding of hill contours a number of islands were considered rising up out of the level sea. In considering valley contours we shall think of the valley as being cut into a perfectly level plain.

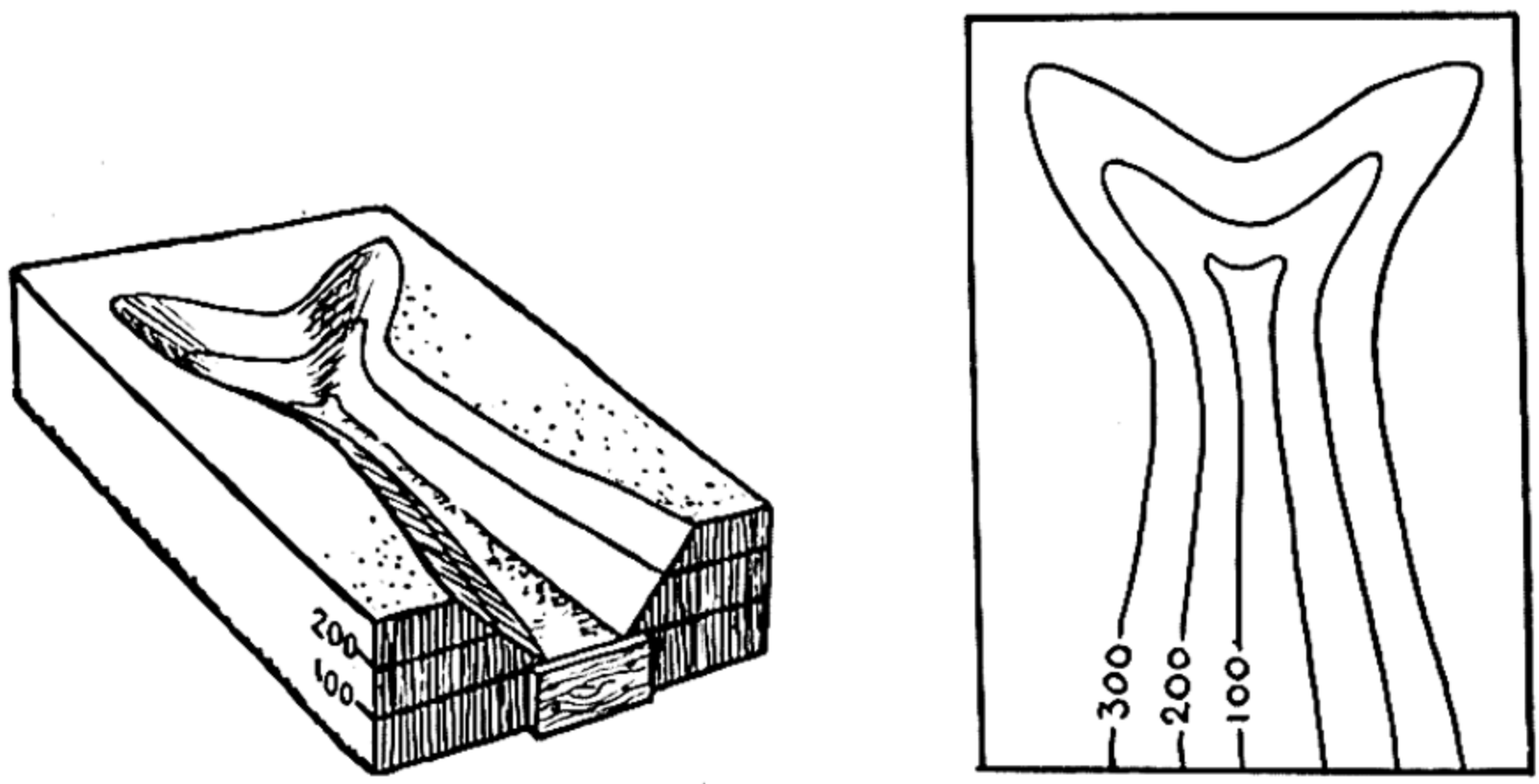


FIG. 48.—A DOUBLE-HEADED VALLEY.

In the map are the contours of a double-headed valley. In the sketch the same valley is drawn with a lake occupying its lower part up to the 100-feet line. Imagine what the valley would look like, first, if the water drained away, and, secondly, if it rose to the 200-feet line.

B. 4. Copy the map and shade it for height.

SIDE VALLEYS

In Fig. 49 the water has risen to the 200-foot line.

Compare the map with the picture and think what the latter would look like without the water.

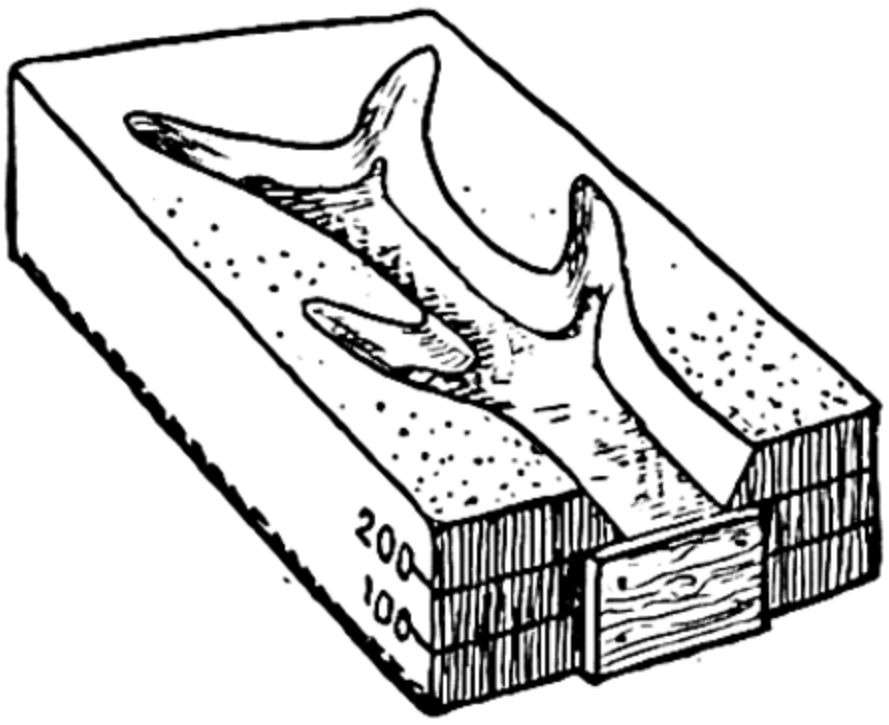


FIG. 49.—VALLEY WITH SIDE BRANCHES.

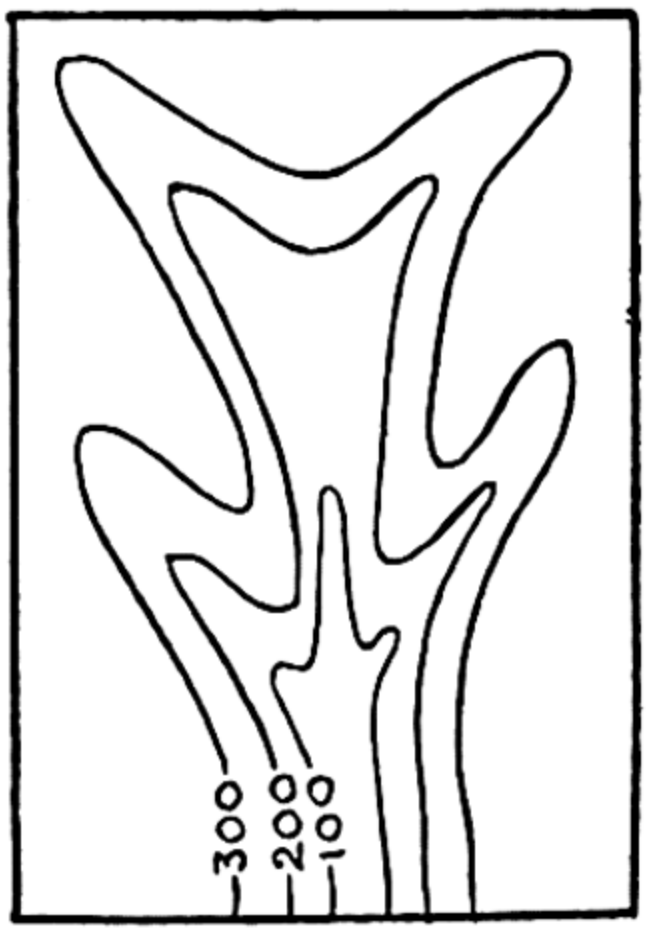


FIG. 49A.—THE MAP.

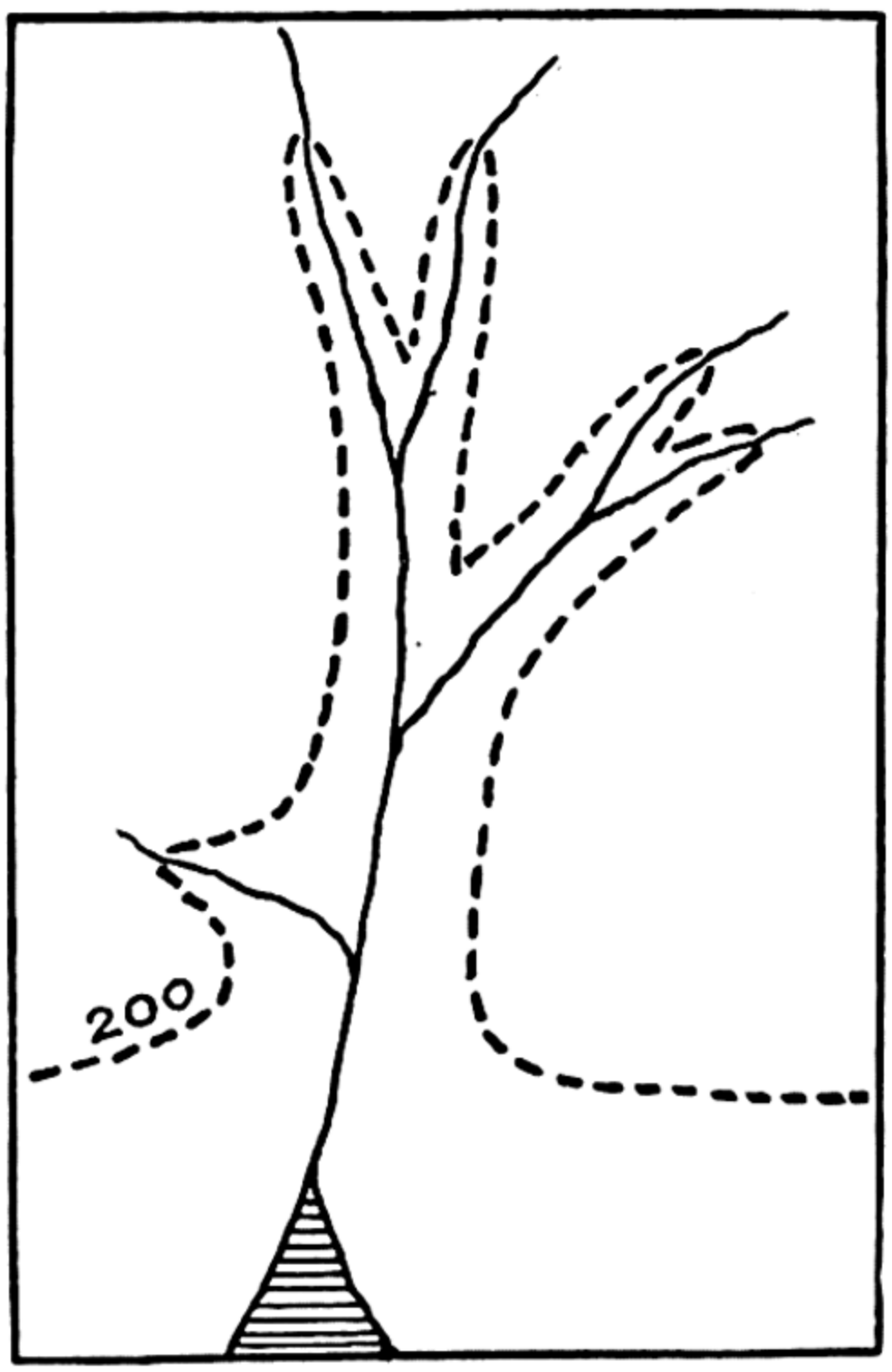


FIG. 50.

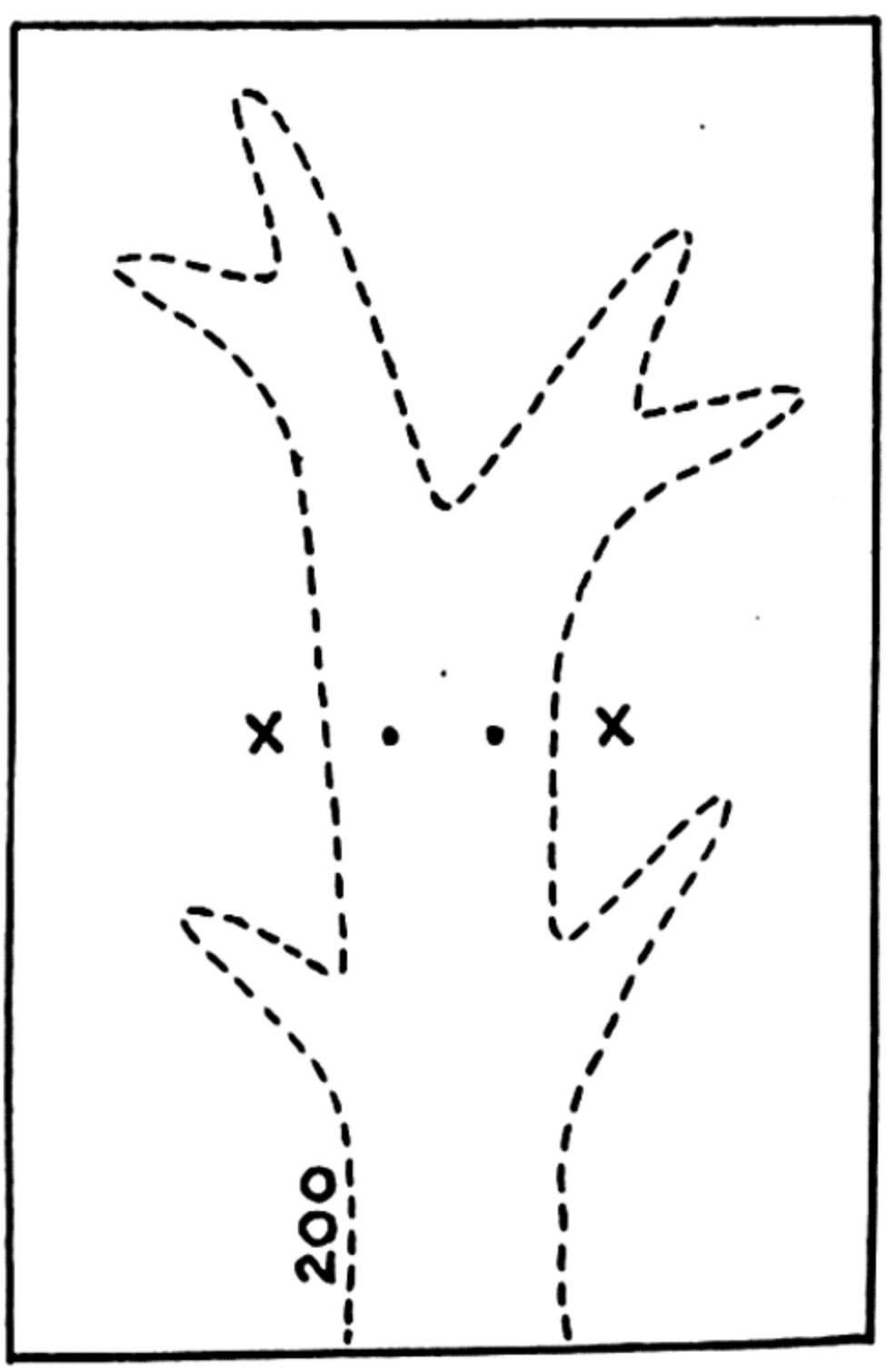


FIG. 51.

B. 5. Copy the map (Fig. 49A) and shade it for height.
B. 6. Trace the 200-feet line and the rivers in Fig. 50. Add the 100-feet contour.
C. 8. Trace the 200-feet line in Fig. 51. Draw the 100-feet contour through the dots and the 300-feet through the crosses. Add the rivers.

A PASS

When two valleys are in line, like those in the sketch, the passage from one to the other forms a " pass."

B. 7. Copy the map and shade it for height. Add two rivers.

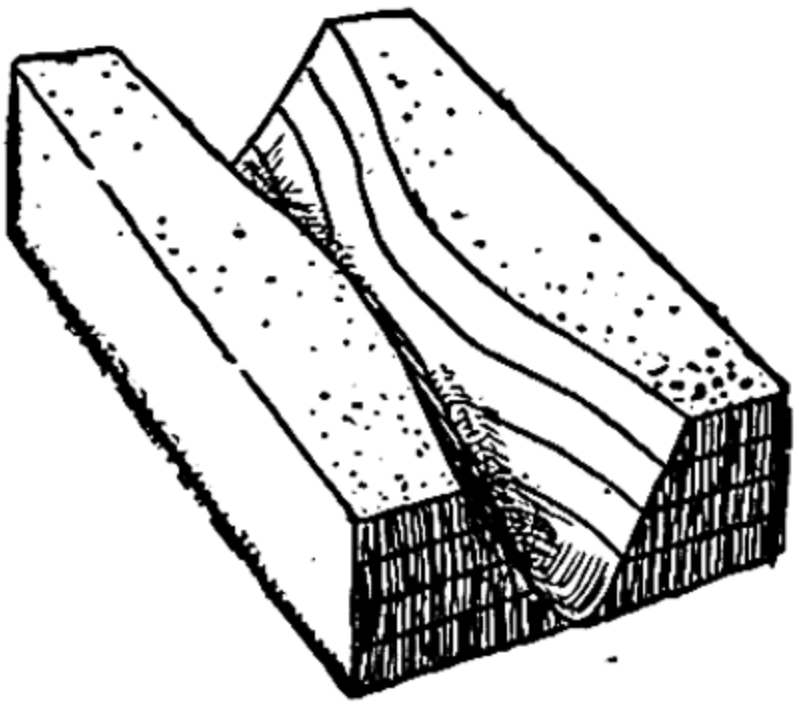


FIG. 52.—A PASS.

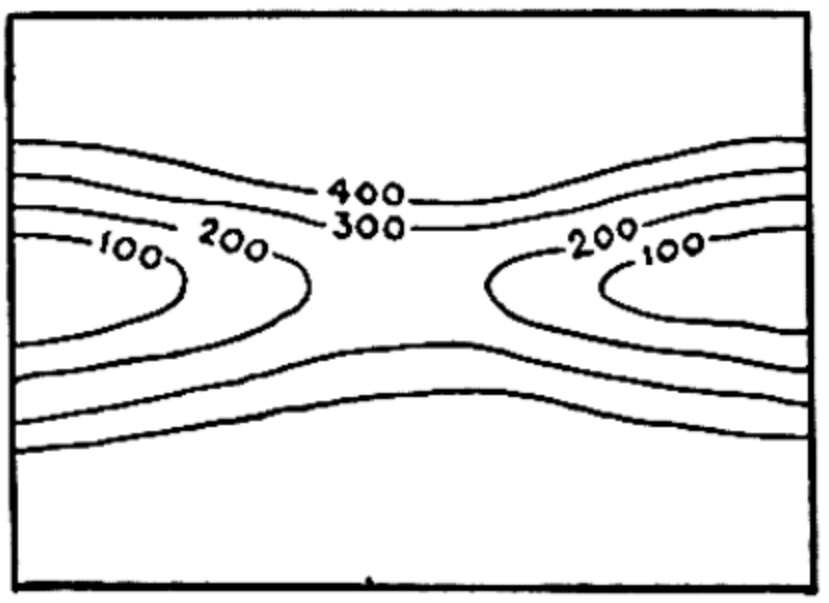


FIG. 53.—MAP OF A PASS.

FINDING THE WAY INTO HARBOUR

In Fig. 54 is a ship sailing between two buoys into Radshaw Harbour. The buoys are moored where the water is 10 feet deep. Between them it is deep enough for the ship; outside them there is the danger of grounding.

In Fig. 55 the land is shaded and the pier to which the boat will be moored is seen jutting out

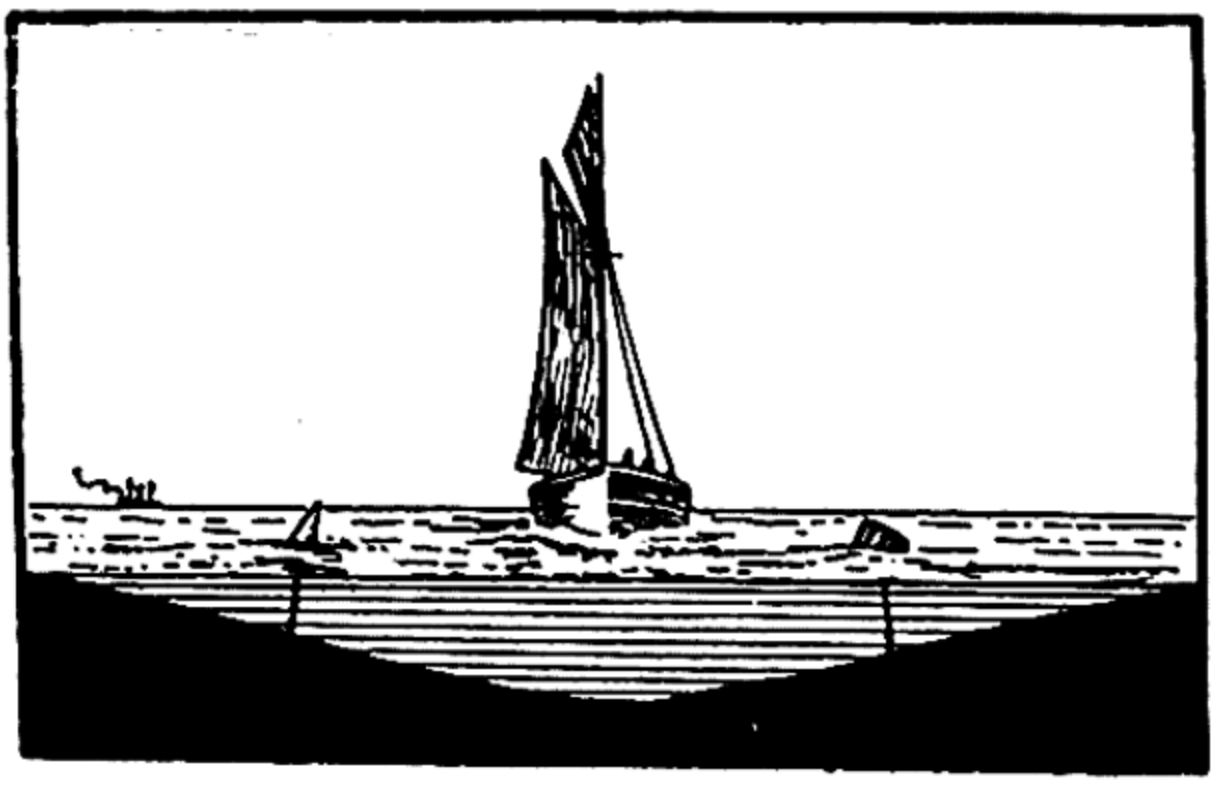


FIG. 54.—BUOYS MARKING CHANNEL.

into the water. The numbers give the depth of the water in feet and the black dots are the lines of buoys. Notice that one of them is midway between the 8 and 12, and that another is between the 3 and 14, but much nearer to the 14.

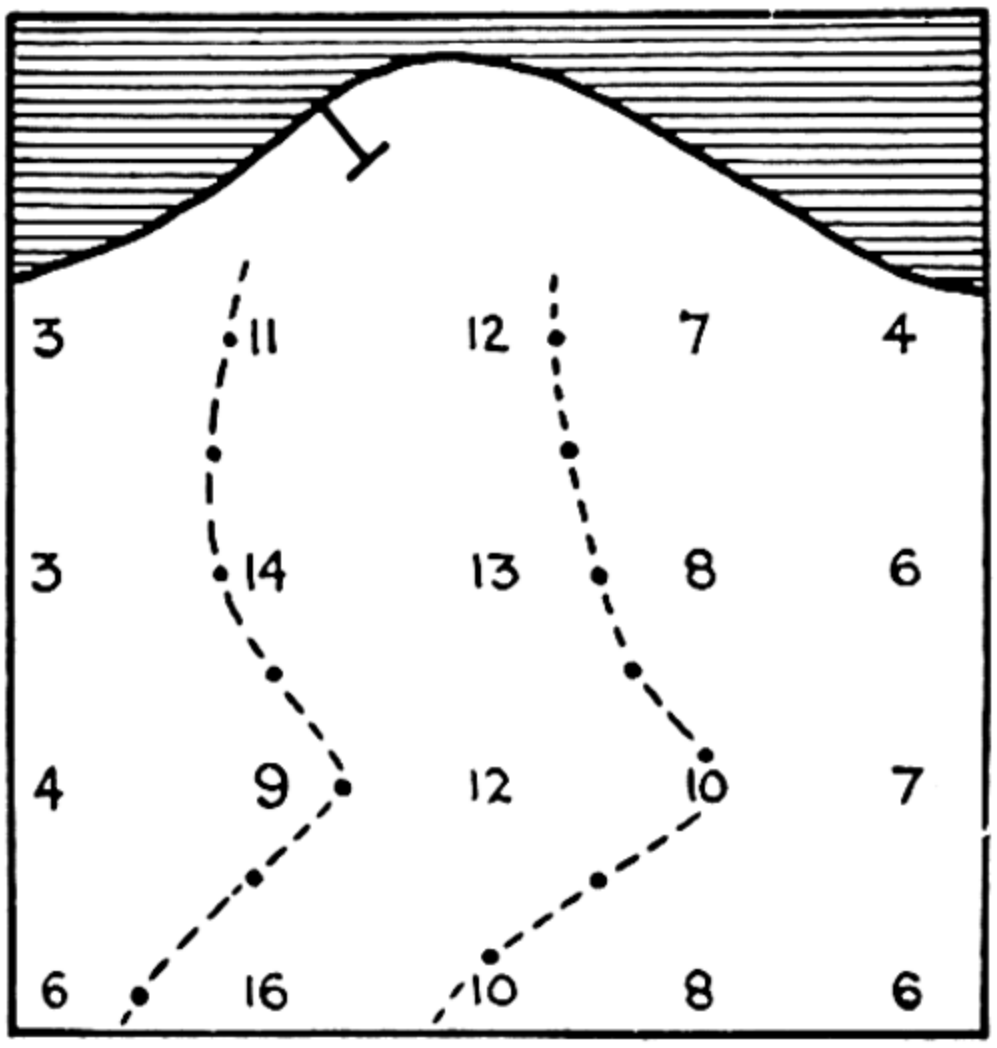


FIG. 55.—MAP SHOWING THE CHANNEL.

On actual charts depths are usually given in fathoms, and of course the numbers are never so regularly arranged as they are here.

Dredging was necessary in the case of Radshaw Harbour to make the water deep enough for ships to reach the pier, but the movement of the water

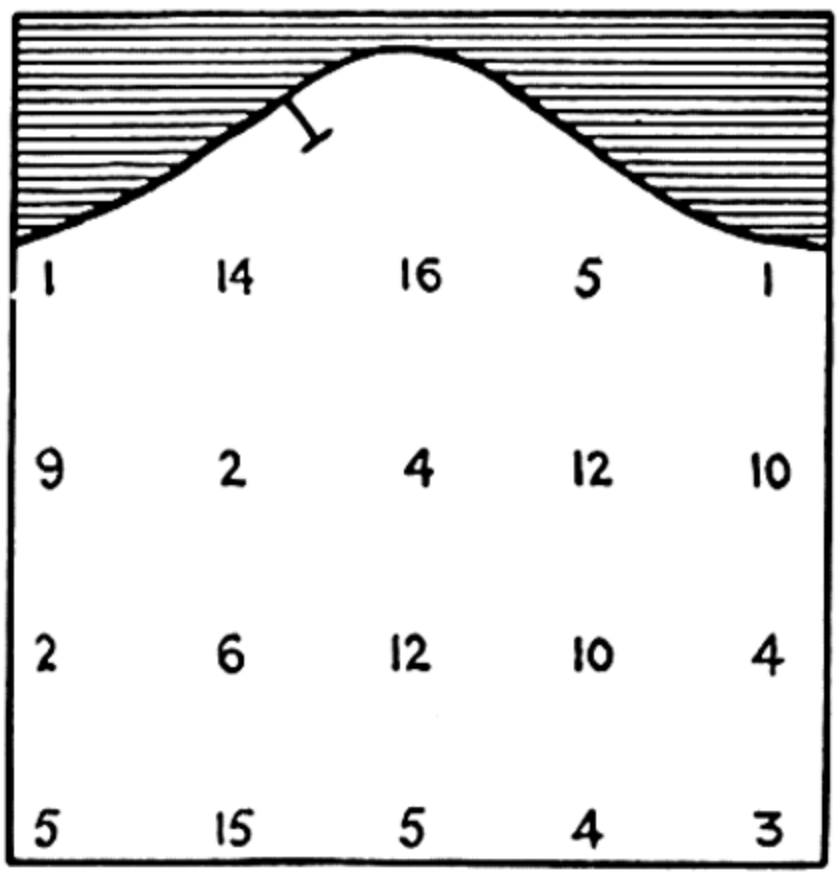


FIG. 56.

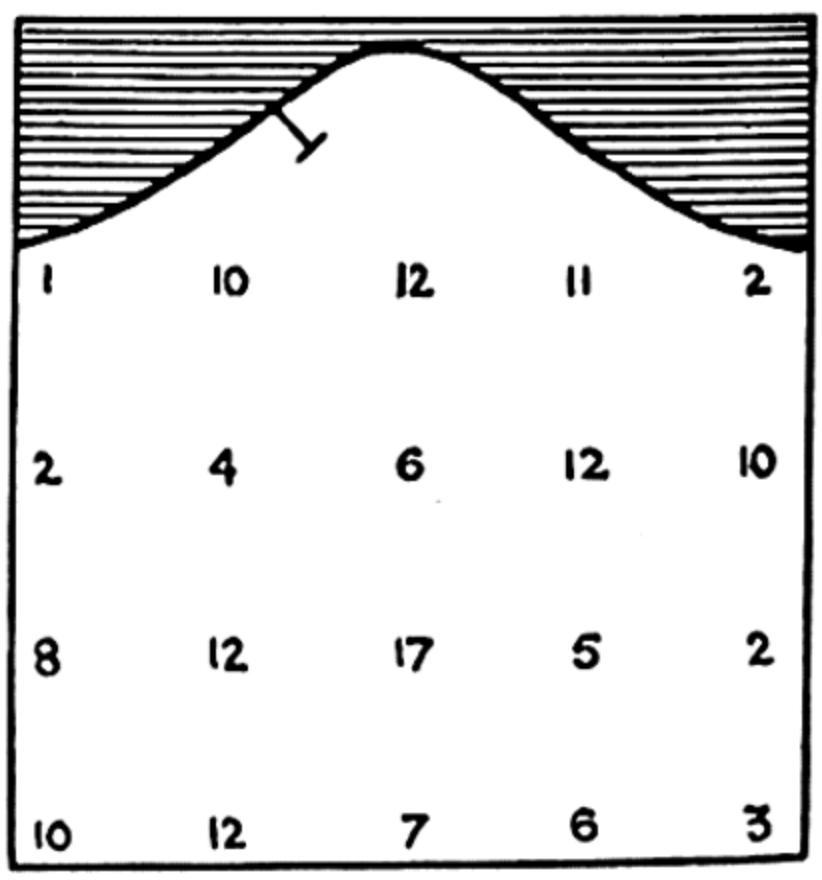


FIG. 57.

has caused the position of the navigable channel to alter continually. Figs. 56 and 57 show the depths on two former occasions.

(For the following exercises draw 3-inch squares.)

B. 8. Copy Fig. 55 and shade in all the parts where the ship cannot go.

C. 9. Copy Fig. 56 and mark out the channel deeper than 10 feet.

C. 10. Copy Fig. 57 and mark out the channel deeper than 10 feet.

C. 11. In Fig. 58 the channel is marked out, but there are no numbers to show the depths. Copy the chart and add suitable numbers, leaving a channel for ships needing not less than 10 feet of water.

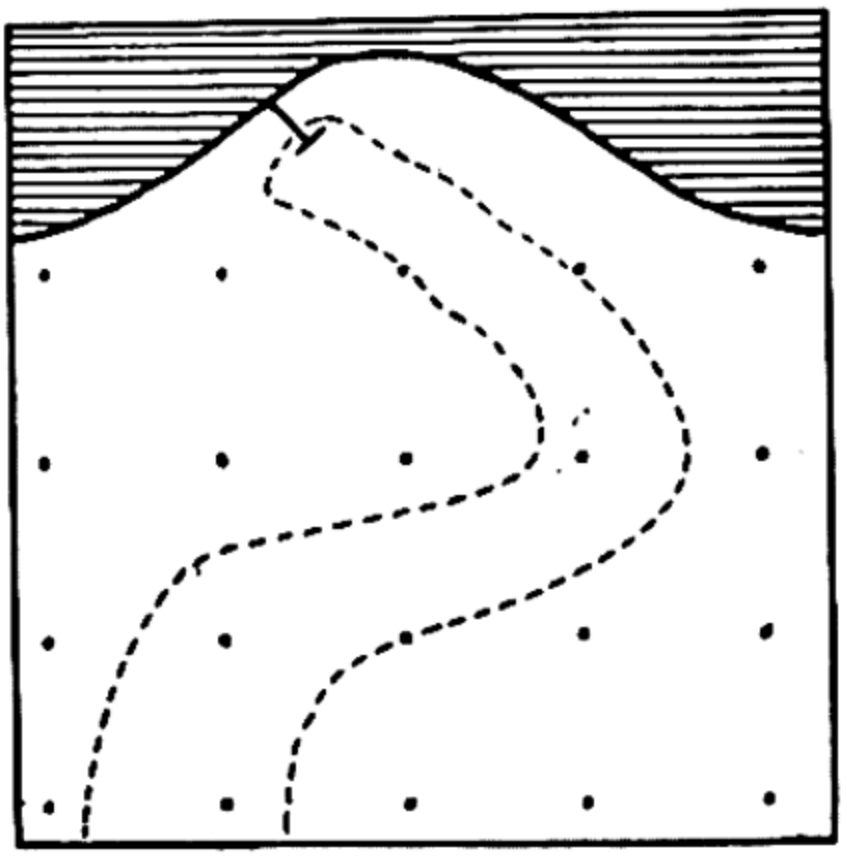


FIG. 58.

A SECTION ACROSS THE HARBOUR

In drawing the sections through the island the same scale was used for vertical heights and horizontal distances. Such sections are said to have a "natural" scale.

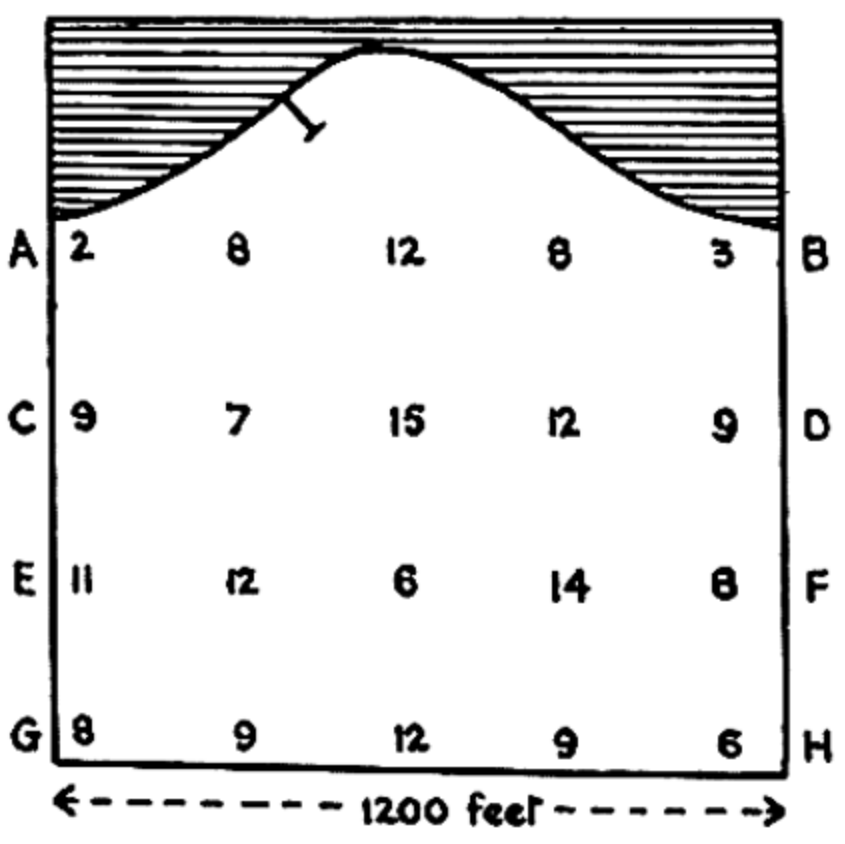


FIG. 59.

When we draw a section on a map or chart it is not always possible to use the same scale for heights and distances. In making a section from the chart in Fig. 59 we have to use a horizontal scale of more than 300 feet to an inch in order to get it on the page. We cannot

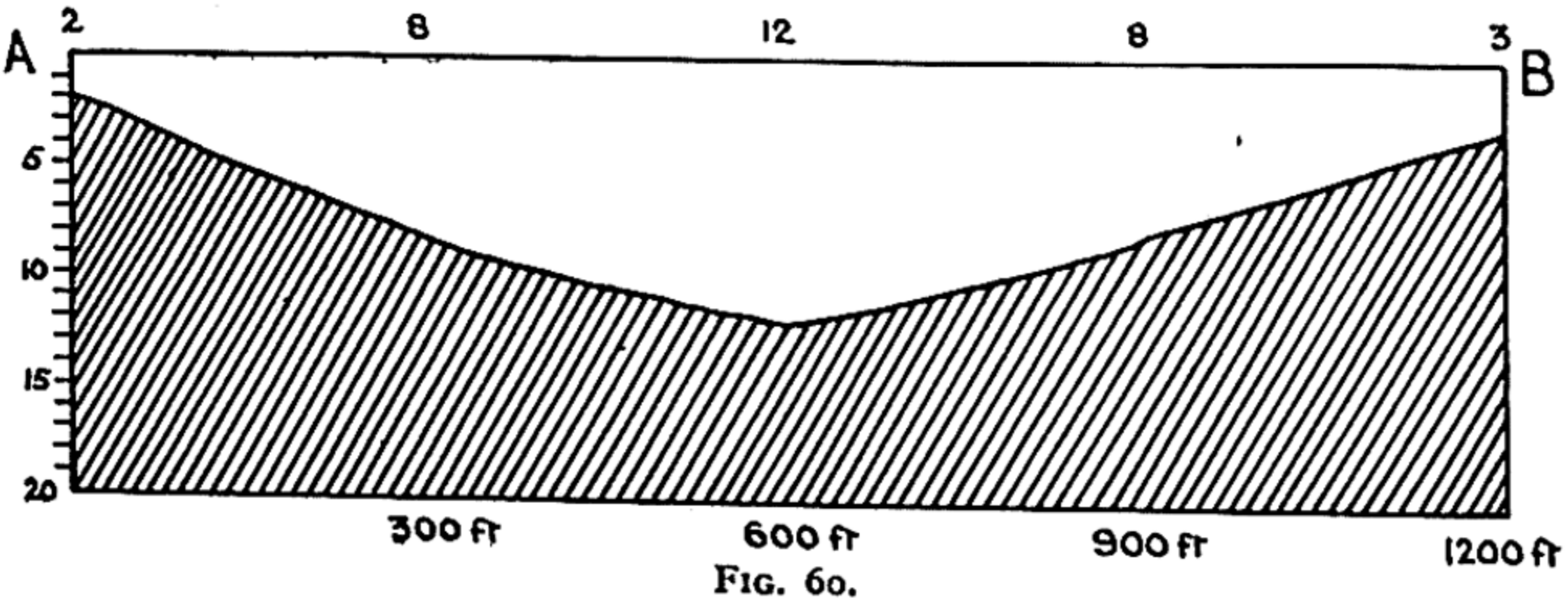


FIG. 60.

use this for the depths, however, as the deepest sounding is only 15 feet, or one-twentieth of an inch on the scale.



FIG. 61.

To get over the difficulty all the depths have been multiplied by twenty, giving a vertical scale of 15 feet to an inch, which allows us to plot the smallest depths easily.

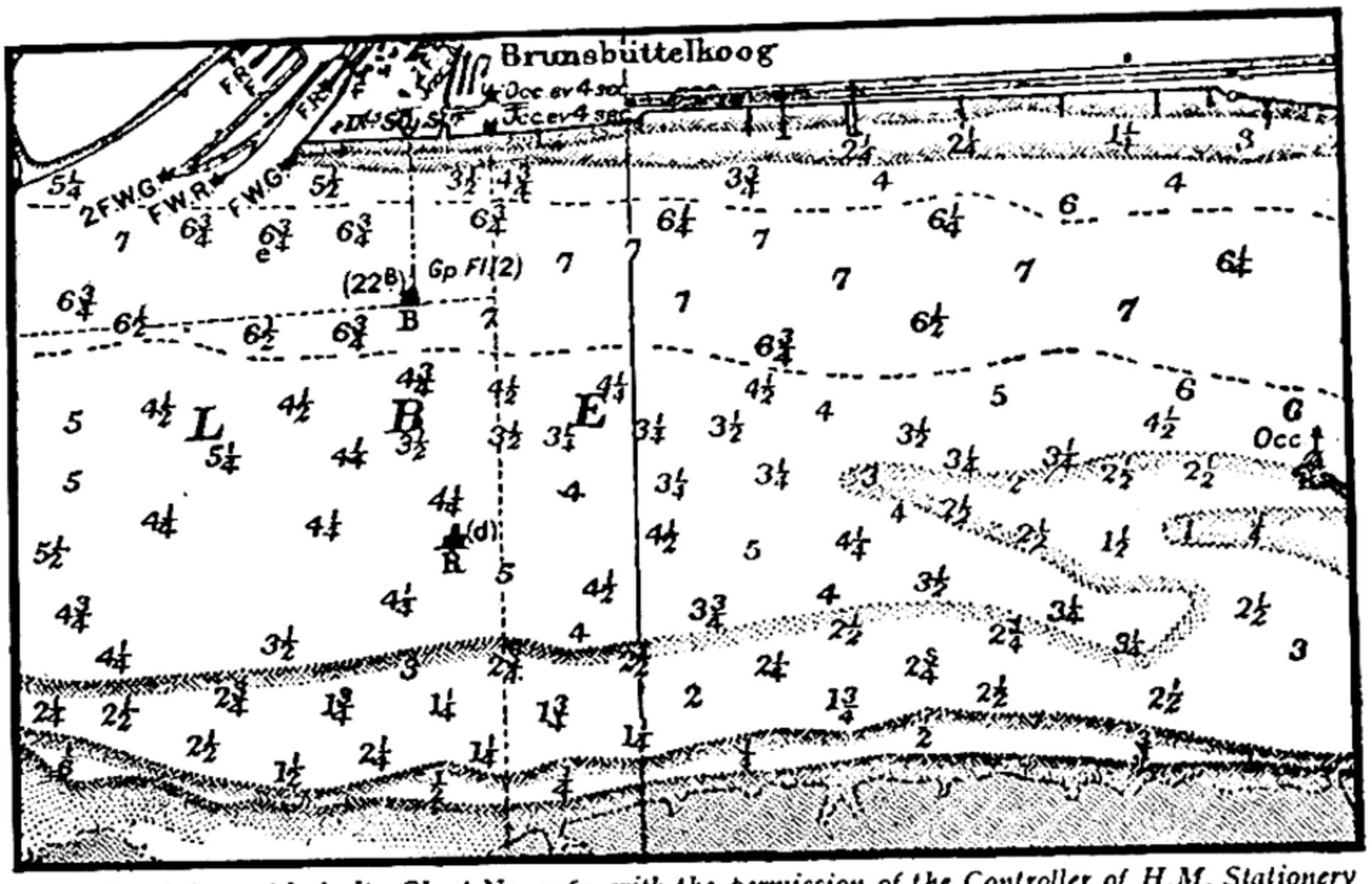
The extent to which this alters the shape may be seen by comparing the sections through a soup plate in Fig. 61. The top drawing is "natural" scale, while in the lower the vertical scale is exaggerated ten times.

C. 12. Re-draw the section from A to B in Fig. 59, making the distance between the numbers along the top 1 inch, and the length of a foot on the vertical scale one-sixteenth of an inch.
C. 13. Draw the section between C and D.
C. 14. Draw the section between E and F.
C. 15. Draw the section between G and H.

THE ENTRANCE TO THE KIEL CANAL

Fig. 62 is a piece of one of the British Admiralty Charts, showing the junction of the Kiel Canal with the River Elbe. The numbers give the depth of the water in fathoms, and contour lines are drawn at 1, 3, and 6 fathoms. Between the two 6-fathom lines is the deep channel that is used by ships, running right across the map.

In the middle of this channel is a buoy (22B) with two flashing lights. At the actual entrance to the Canal are lights marked F W R, F W G for the guidance of shipping at night. By the eastern edge of the map is a light on a buoy which is marked Occ, and which is no doubt put there as a warning against the very shallow water in that part so close to the deep channel.



(Reproduced from Admiralty Chart No. 2469 with the permission of the Controller of H.M. Stationery Office and of the Hydrographer of the Navy.)

FIG. 62.—CHART OF THE ENTRANCE TO THE KIEL CANAL.
Scale 1 : 51400

LIGHTS :

F. Fixed. W. White. G. Green. R. Red. Occ. Occulting. Gp. Fl. Group of flashes.

D. 1. Draw a section along the eastern edge of the map with a vertical scale of $\frac{1}{16}$ inch to a fathom.

D. 2. Draw a section along the line crossing the middle of the map on the same scale.

D. 3. Draw a section along the western edge of the map. Vertical scale $\frac{1}{16}$ inch to a fathom.

D. 4. What is the exaggeration in vertical scale in the above exercises ?

QUESTIONS ON CHAPTER FOUR

A. 1. What is meant by the relief of a country ?

A. 2. How is relief shown on a map ?

A. 3. What is a contour line ? (Illustrate your answer with a sketch and a plan.)

A. 4. How do you judge where the steeper and the gentler slopes are on a contour map ?

B. 1. Explain, with the aid of a simple example, how you would draw a section across a relief map.

PART II

THE EARTH AS A GLOBE

Chapter Five

THE EARTH AND THE SCHOOL GLOBE



[*Photo by E. J. O.*

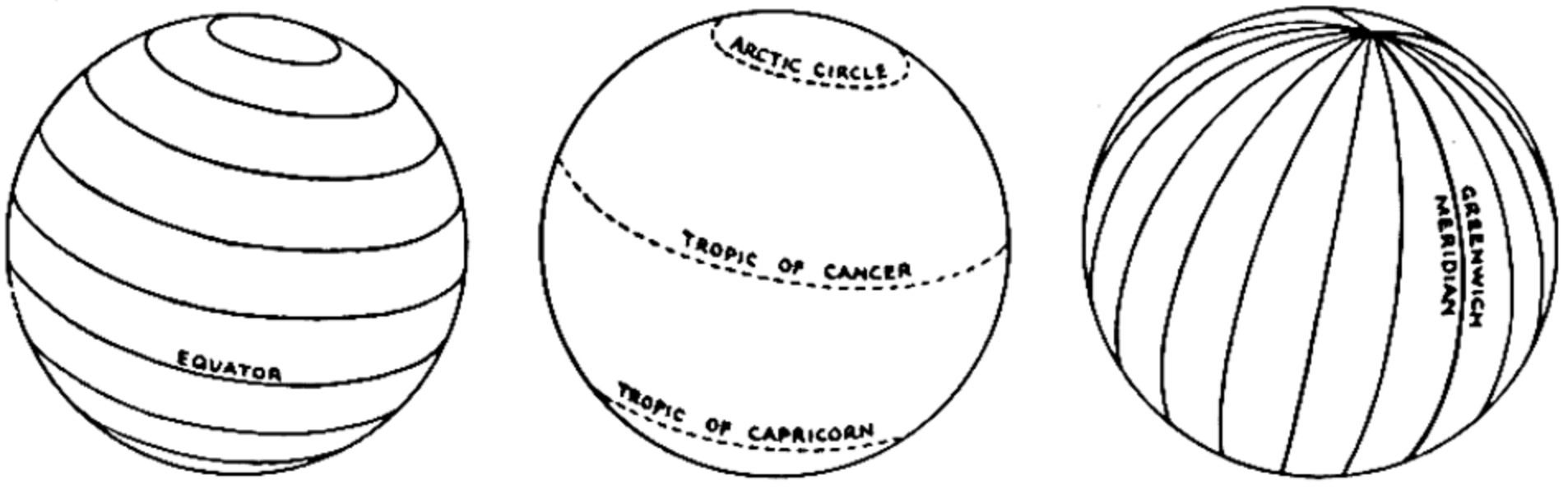
FIG. 63.

THE SUN LINES

THE positions of the lines on the globe marking the boundaries of the zones are determined by the way the sun shines on the various parts. In the Torrid Zone it is always high in the sky at noon and at every place within that zone is overhead twice during the year.

Inside the Polar Circles the sun is never very high in the

sky. In midwinter it does not rise at all, and to make up for this does not set at midsummer for weeks or even months: weeks near the edge of the circle and months farther in.



Parallels. Sun Lines. Meridians.

FIG. 64.—LINES ON THE GLOBE ON THE OPPOSITE PAGE.

In the Temperate Zones there are never any days when the sun neither rises nor sets, as there are in the Frigid Zones, and the overhead sun is never experienced as it is in the Torrid Zone.

The shapes of the zones can best be understood from the picture of the globe (Fig. 63). The Torrid Zone is a "belt" on both sides of the Equator with two equal boundaries.

The North Frigid Zone, which is not really a "belt" but a "cap," has the North Pole at its centre.

The North Temperate Zone occupies the space between the other two, its warmer boundary being nearly two and one-third times as long as the cooler one.

On the map in the front cover the distances down the middle line are in proportion to those on the Earth itself. Measure the following distances along that line and compare them:

A. 1. (*a*) The Equator to the Tropic of Cancer, and the Equator to the Tropic of Capricorn.
(*b*) The North Pole to the Arctic Circle, and the Equator to the Tropic of Cancer.

A. 2. The width across the Arctic Circle, the width between the Tropics, and the width across the North Temperate Zone.

A. 3. Draw a diagram of the globe with the names of the zones and their boundaries outside the circle. In the Temperate Zones write

"Sub-tropical" near the Tropics, "Cool Temperate" in the half nearer the Polar Circle, and "Warm Temperate" near the sub-tropical part.

A. 4. In which of the zones do you live? If you travelled southward, into which zone would you come next? If northward?

A. 5. Write down from the map in the front cover which of the following places have the midnight sun in summer, and which sometimes have the sun overhead. In each case say how you can tell:

Nova Zembla	Rio
Winnipeg	Northern Greenland.
Bombay	Naples
Hammerfest	Yokohama

Atlas Exercises (these can be answered in part from the map inside the cover):

A. 6. Through which continents, oceans, and large islands does the Equator run?

A. 7. Through which continents and oceans does the Tropic of Capricorn pass? What cities are near it?

A. 8. Through which continents and oceans does the Tropic of Cancer pass? What cities are near it?

A. 9. What lands lie within (*a*) the Arctic Circle, (*b*) the Antarctic Circle?

SOME PROPERTIES OF THE GLOBE

If we withdraw the axis of the school globe and mark it with chalk to show the length of the diameter we shall find that this length goes round the equator rather more than three times. If instead of using the rod we take a piece of

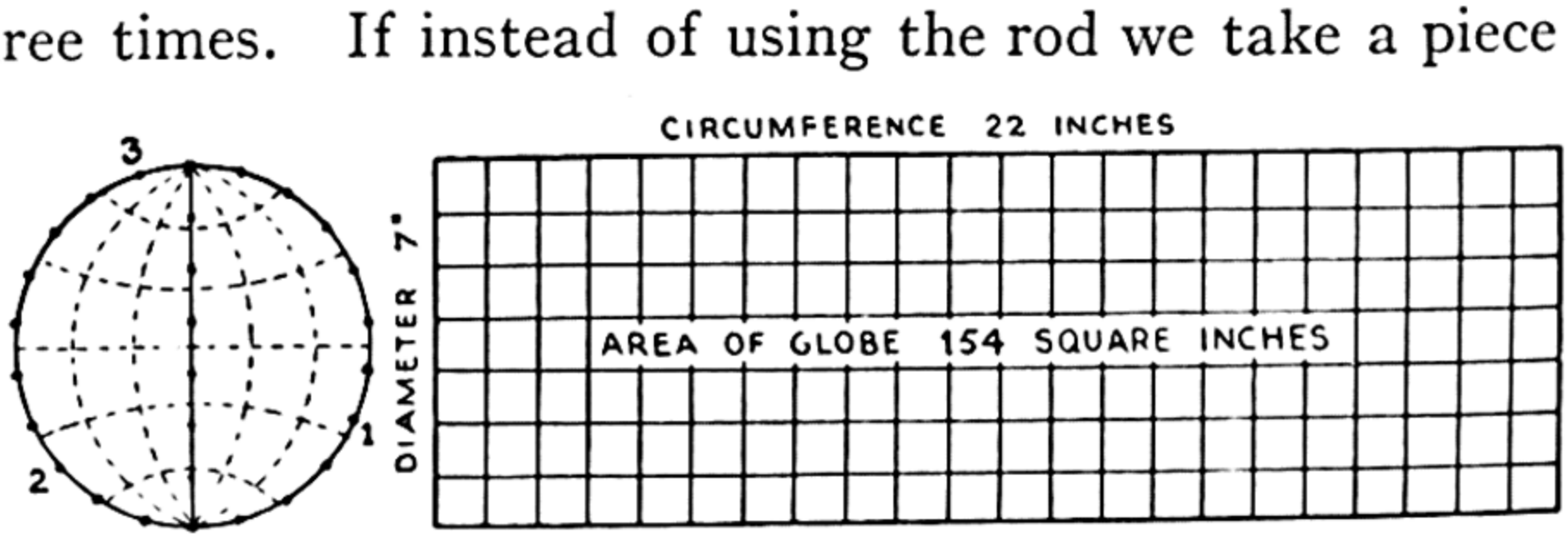


FIG. 65.—THE AREA OF THE SURFACE OF A SPHERE.

string or a ribbon of paper as long as the diameter, the result will be more accurate, viz. $3\frac{1}{7}$ times (3·14). A globe that is seven inches in diameter will therefore have a circumference of $7 \times 3\frac{1}{7}$ or 22 inches.

To find the area of the surface of this globe we multiply the diameter by the circumference. With a seven-inch globe this gives 22 × 7 square inches or 154 square inches.

THE SIZE AND SHAPE OF THE EARTH

In this book we shall consider the Earth to be a sphere. At one time men of science believed it to be a perfect sphere, apart, that is, from the slight roughness on the surface due to the mountains. It is now known, however, that the distance through it at the Equator is about one three-hundredth part longer than the distance through between the poles.

Here are the dimensions of the Earth given in two sets of numbers :

	To the Nearest Mile.	In Round Numbers.
Polar Diameter . .	7,900 miles	8,000 miles
Equatorial Diameter .	7,927 miles	8,000 miles
Circumference of Equator	24,902 miles	25,000 miles
Circumference through Poles . . .	24,860 miles	25,000 miles
Area of Surface . .	196,971,984 sq. miles	200,000,000 sq. miles (25,000 × 8,000)

More exact measurements are given on page 192.

MEASURING DISTANCES ON THE GLOBE

Except in a few special cases, long distances, such as that from London to Calcutta, cannot be measured on a flat map with any degree of accuracy, as it is impossible to draw a map of a large area that shall be true to scale all over. Scales are always given on maps of continents, but generally they are correct only near the centre. Long distances, therefore, have to be measured on a globe, and a scale of miles must be made for the purpose.[1]

[1] On the map of the world at the beginning of the book all distances measured outwards from England are correct by the scale ; but such a distance as that from Calcutta to Shanghai will not be correct.

A SCALE OF MILES FOR THE SCHOOL GLOBE

Take a strip of paper an inch wide and long enough to go half-way round the globe, joining two or more pieces together

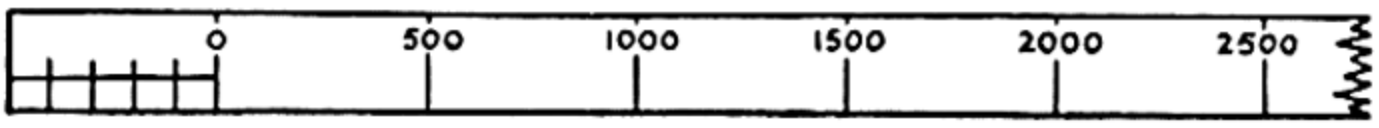


FIG. 66.—A SCALE OF MILES FOR THE GLOBE.

if necessary. Divide the strip into twenty-five parts, each of which will represent five hundred miles.

B. 1. Draw a scale of miles for a fourteen-inch globe to measure up to 4,000 miles. (A fourteen-inch globe means one with a diameter of 14 inches; 4,000 miles will therefore be 7 inches.)

B. 2. Make a scale to measure up to 13,000 miles on your school globe, and with it find the length of the shortest distance between the following places:

North Pole and South Pole. Equator and North Pole. Quito and Singapore. London and Karachi. New York and Yokohama. Valentia Is. and St. John's (Nfd.). Buenos Aires and Cape Town.

A SCALE OF DEGREES

B. 3. Make a scale of degrees for the globe by laying the edge of a strip of paper along the Equator and marking off the degrees required.

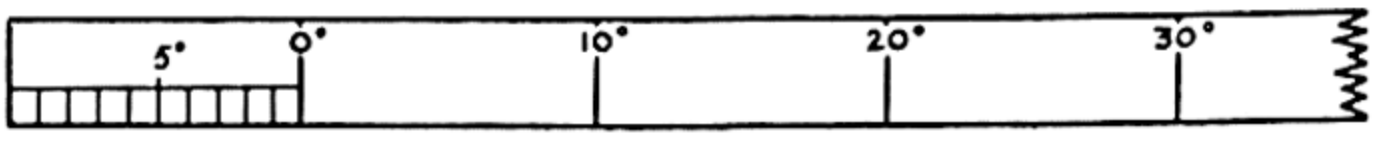


FIG. 67.—A SCALE OF DEGREES FOR THE GLOBE.

Measure the number of degrees between the pairs of places in the preceding exercise.

DESCRIBING OUR POSITION ON THE EARTH'S SURFACE

On land we can give the position of a place by reference to such things as rivers, roads, and buildings, and the distances from these. But in mid-ocean, where there are no rivers or buildings or streets, some other means must be adopted for describing the position of a ship.

The method chosen is to draw two lines on the globe which cross each other at right angles in the Gulf of Guinea. They

are the Equator and the Greenwich Meridian, and we can describe the position of every place in the world by reference to them.

Find the two lines on the photograph of the globe on page 44.

The Greenwich Meridian runs from the North Pole to the South Pole, passing through Greenwich Observatory on the way. Outside the Observatory its course is indicated by a line cut in a piece of stone let into the ground with the words "Greenwich Meridian" carved beside it.

The Greenwich Meridian is sometimes spoken of as the "Prime Meridian."

PARALLELS OF LATITUDE

The distance of a place from the Equator is its latitude.

The distance between the Equator and the North Pole is divided into 90° and circles are drawn at every degree parallel to the Equator. These circles are called Parallels of Latitude.

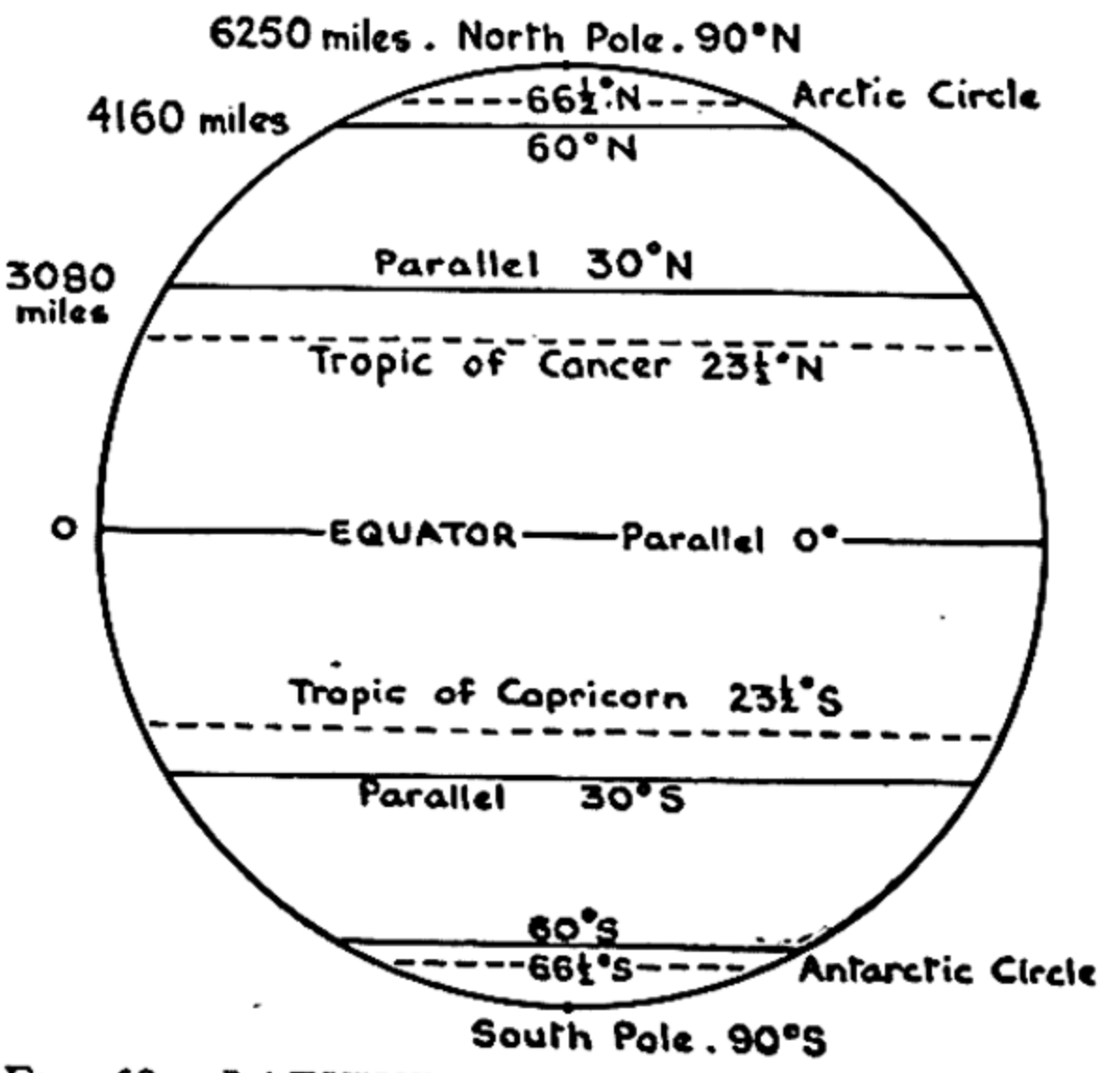


FIG. 68.—LATITUDE, DEGREES, AND MILES.

Measure the distance between two lines of latitude on the globe. Test the distance in all parts and notice that it never changes.[1]

The Equator is marked 0° and the other parallels are numbered from 1° North Latitude to 90° North Latitude, which is the North Pole.

[1] On the Earth itself slight changes can be measured because it is not a sphere.

The distance between the Equator and the South Pole is similarly divided and the parallels numbered from 1° South Latitude to 90° South Latitude, which is the South Pole.

Latitude is always expressed in degrees for the convenience

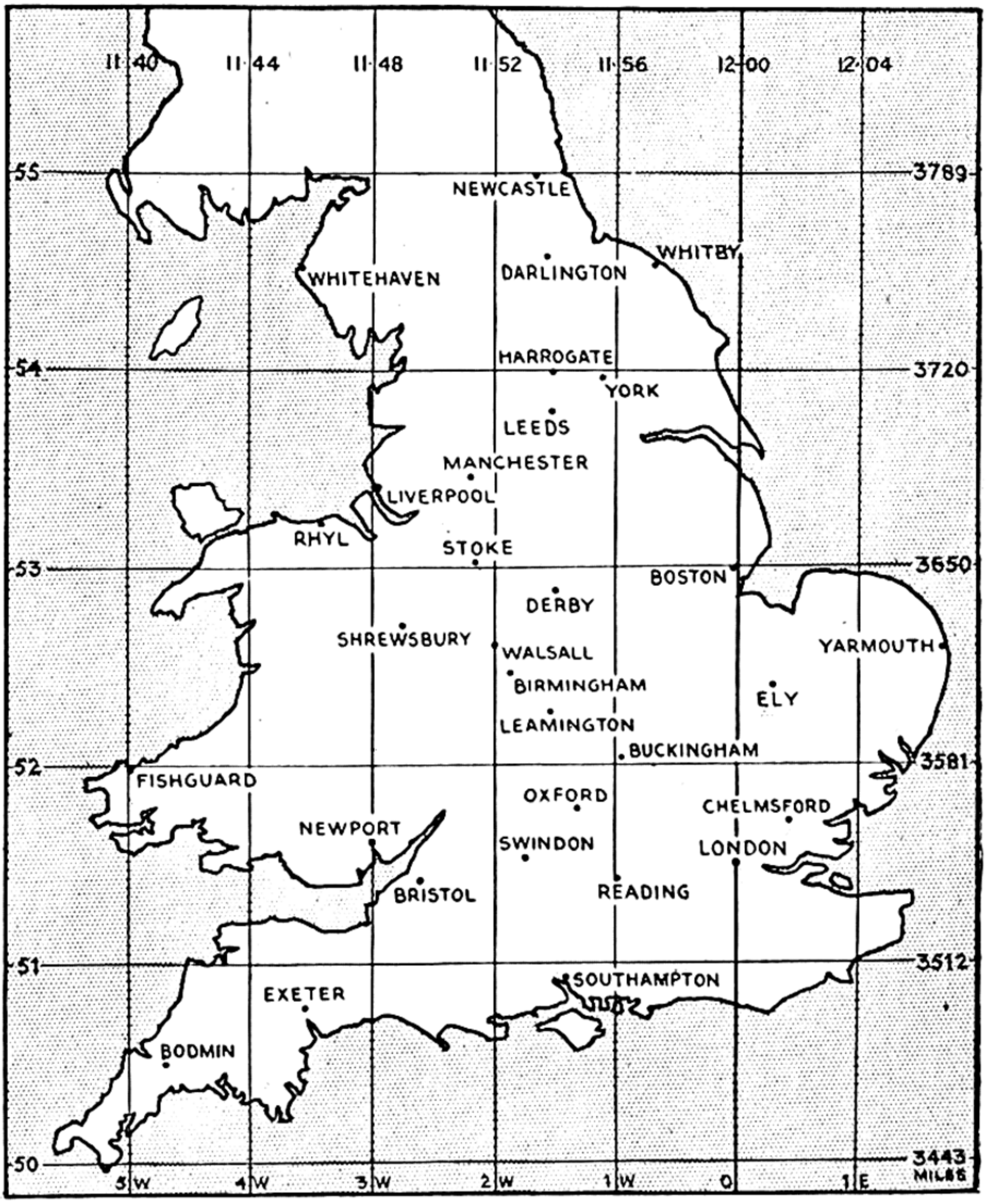


FIG. 69.—ENGLAND AND WALES.

of seamen, but for ordinary folk it would be much more understandable to have it in miles, one degree of latitude being roughly 70 miles. This has been done on one side of Fig. 68, and on the above map of England and Wales.

A. 10. Copy Fig. 68, but put in only parallels 0°, 30° N. and S., 60° N. and S. Write the name on each line thus: Parallel 30° S.

Look at the map on page 50 and find Newcastle. It is on parallel 55° N.; or we may say that it is in latitude 55° N., or that its distance from the Equator is 55°. London, half-way between parallels 51° and 52°, is in latitude 51½° N.

A. 11. Give the latitude of the following places:
Liverpool, Manchester, Reading, Bristol, Birmingham, Exeter.

A. 12. What towns lie in or near these latitudes:
54° N., 52° N., 53° N., 52¼° N., 51¾° N., 54½° N.?

THE LATITUDES OF THE SUN LINES

The Tropics are 23½° from the Equator and the Circles 23½° from the Poles.

A. 13. What is the latitude of the Tropic of Cancer?

A. 14. What is the latitude of the Arctic Circle?

A. 15. Draw a circle with a radius of 1½ inches to represent the Earth. Add a diameter for the Equator and, judging the distances, draw the Circles and the Tropics. Write on each line its name and latitude.

B. 4. What is the width of the Torrid Zone in degrees, from north to south? About how many miles is this?

B. 5. How many degrees across is the North Temperate Zone from north to south? About how many miles is this?

B. 6. How many miles is it, roughly, from the North Pole to the Arctic Circle?

GLOBE OR ATLAS EXERCISES

A. 16. Between which parallels of latitude do the British Isles lie?

A. 17. About how many miles is it then from the Lizard to the Shetlands?

A. 18. Through what towns, countries, continents, and seas does parallel 60° pass?

A. 19. What places in the world lie in the same latitude as the Lizard?

B. 7. What countries in Eurasia and North America lie between the north and south limits of the British Isles? Give their principal cities within these limits.

B. 8. What, roughly, is the latitude of your school? What other places in the world are the same distance from the Equator?

B. 9. Find which places in the southern hemisphere are the same distance from the Equator as you are?

B. 10. What do we mean when we say that Cairo is in the same latitude as New Orleans? Find from the map of the world what their latitude is. What other cities are in roughly the same latitude?

B. 11. From the map of the world give the latitudes of Durban, San Francisco, Para, Madrid, Sydney, Shanghai.

LONGITUDE

On the globe in the picture (Fig. 63) twenty-four meridians have been drawn, the distance between them being 15°. Find 0°, 15° W., 30° W., 45° W., 60° W., 75° W., 90° W., 15° E., 30° E. Find also meridian 180°, which may be regarded as

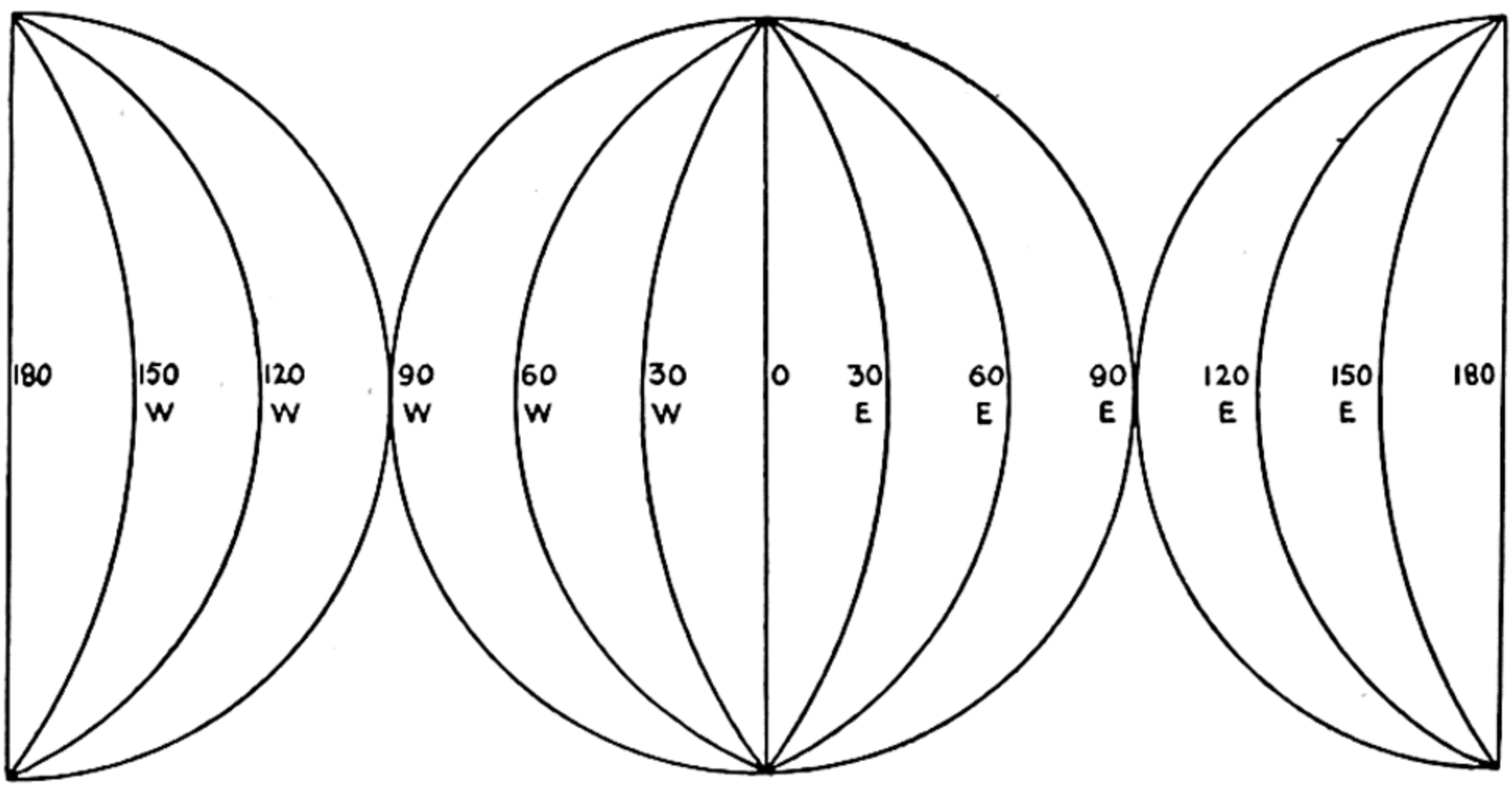


FIG. 70.—MERIDIANS OF LONGITUDE, OR SAME-TIME LINES.

the continuation of the Greenwich Meridian and is neither E. nor W.

In which directions can a ship sail and always keep on the same meridian?

In the above diagram there are twelve meridians 30° apart; if the globe were large enough to put in all the meridians, there would be 360 of them. They have been drawn at every degree on the map of England and Wales (Fig. 69).

The meridian distance of a place east or west from Green-

wich is its longitude. Thus the longitude of Reading is 1° W., because it is on the first meridian west of Greenwich; the longitude of Liverpool is 3° W., because it is on the third meridian west of Greenwich. Boston, due north of Greenwich, is on the Greenwich Meridian; its longitude is therefore 0°. Yarmouth lies in 1½° east longitude.

A. 20. From the map on page 50 find the longitude of the following: York, Fishguard, Newport, Coventry, Walsall.

A. 21. What towns of England and Wales have, roughly, these longitudes:
1° W., 0°, 1½° E., 3½° W., 1½° W.?

GLOBE OR ATLAS EXERCISES—LONGITUDE

A. 22. Through which continents and oceans does each of the following meridians pass:
0°, 180°, 90° E., 90° W.?

A. 23. Through which countries and seas does each of the following meridians pass:
0°, 180°, 90° E., 90° W.?

A. 24. Which is farther west, New York or Valparaiso?

A. 25. Which is farther west, Liverpool or Edinburgh?

A. 26. What is the most easterly part of Great Britain, and which is the most westerly? What is the longitude of each?

A. 27. Find the longitude of Dundee, Stirling, Belfast, Galway, Glasgow.

MERIDIANS AND MILES

At the Equator the meridians are about 70 miles apart, but as we move towards the poles they get closer and closer together, until at parallel 60° there is only half that distance between them. After that they converge rapidly and all meet at the poles.[1] We cannot, therefore, give the longitude of a place in miles from the Greenwich Meridian.

On the map of England and Wales in your atlas measure the distance between two meridians along the northern edge and compare it with the distance between them farther south.

[1] A table of distances is given on page 192.

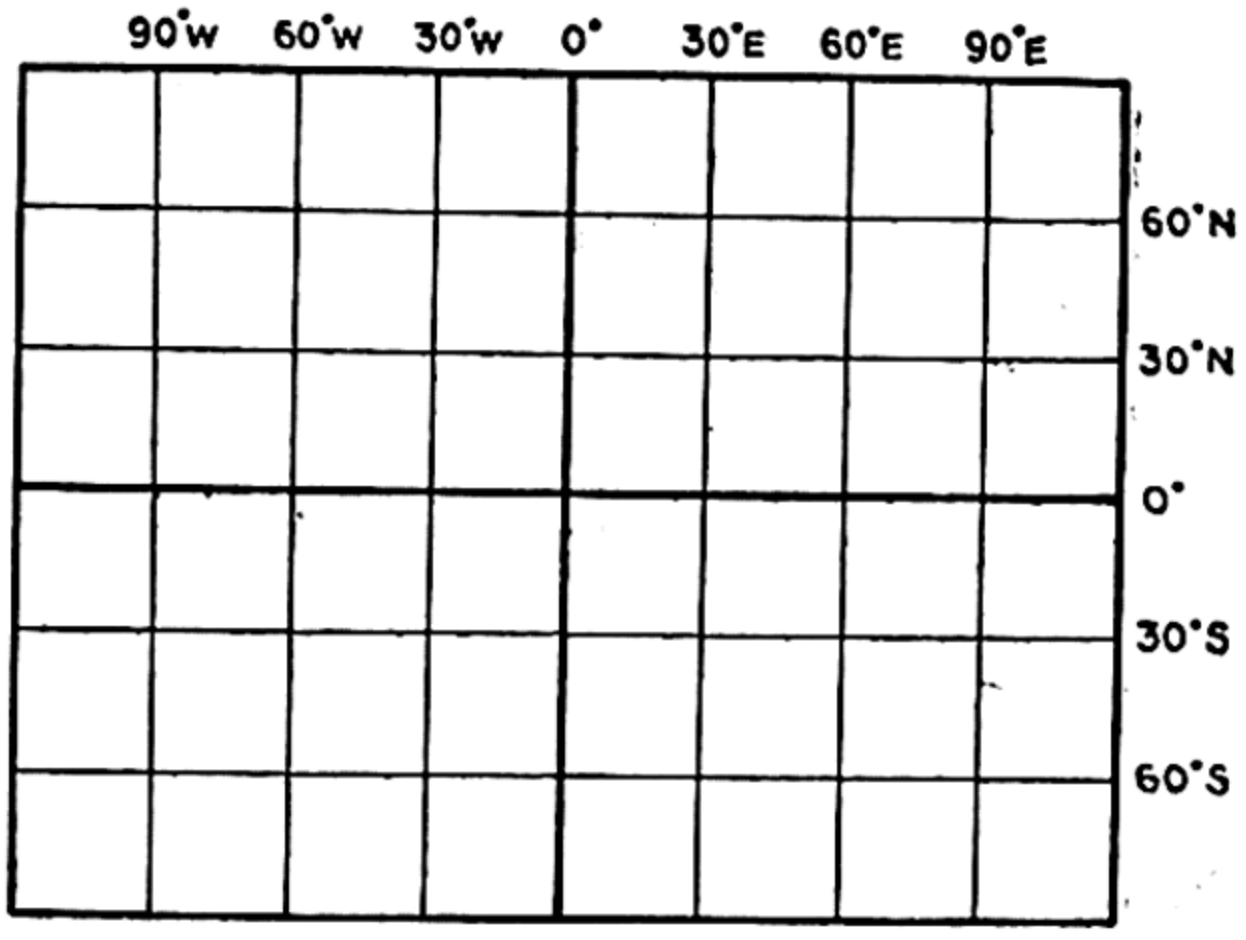


FIG. 71.

LATITUDE AND LONGITUDE EXERCISES

B. 12. Copy Fig. 71 4 inches broad and 3 inches from north to south.

Mark the positions of the following places. (The positions are only approximate.)

Add the name or an initial in each case.

Place.	Position.	
Leningrad . . .	60° N. Lat.	30° E. Long.
Cairo	30° N. Lat.	30° E. Long.
New Orleans . . .	30° N. Lat.	90° W. Long.
Durban	30° S. Lat.	30° E. Long.
Calcutta	Cancer	90° E. Long.
Rio	Capricorn	45° W. Long.
Shanghai	30° N. Lat.	120° E. Long.
Aral Sea	45° N. Lat.	60° E. Long.
S. Orkneys . . .	60° S. Lat.	45° W. Long.
Quito	0° S. Lat.	80° W. Long.

B. 13. Compare the positions with those given in the atlas.

B. 14. Copy Fig. 72, making it $3\frac{3}{4}$ inches broad and $4\frac{1}{2}$ inches from north to south.

Put dots for the following towns and write the initial against each.

B 15. Compare the positions obtained with the positions shown in an atlas.

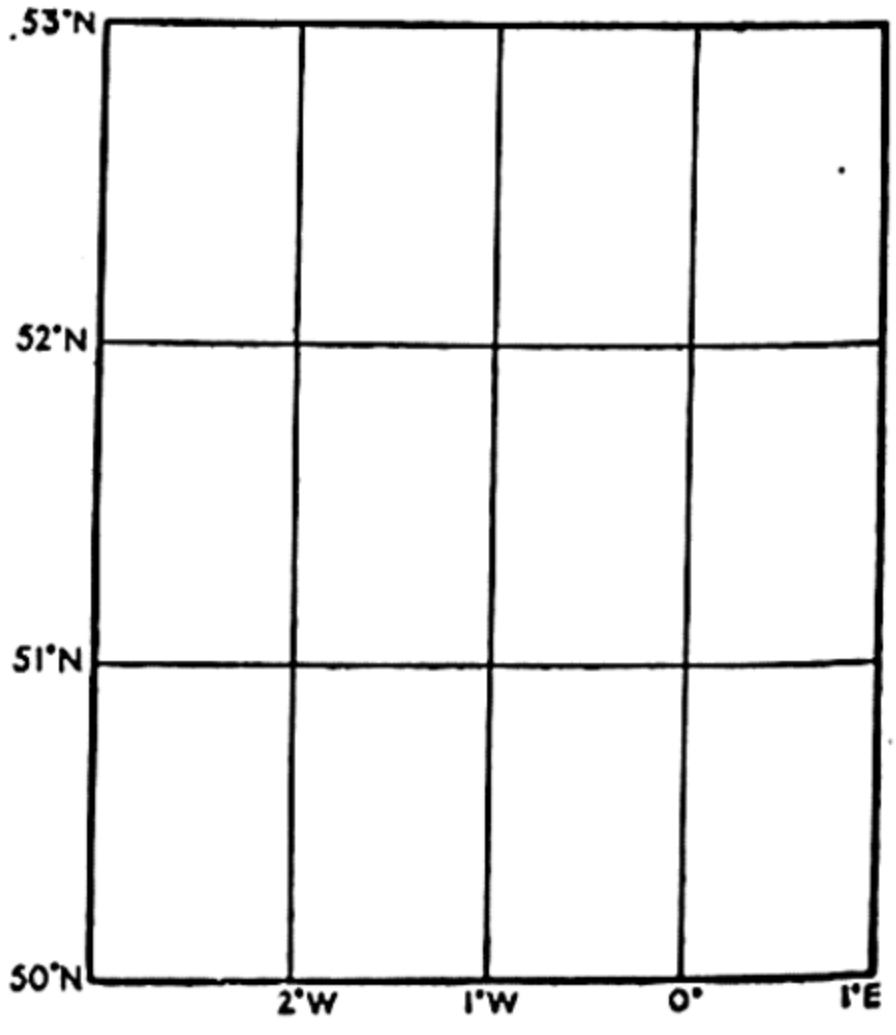


FIG. 72.

Place.	Latitude.	Longitude.
Brighton	50¾° N.	0°
Cambridge	52¼° N.	0°
Harwich	52° N.	1¼° E.
Leicester	52½° N.	1¼° W.
Maidstone	51¼° N.	½° E.
Norwich	52½° N.	1¼° E.
Oxford	51¾° N.	1¼° W.
Peterborough	52½° N.	¼° W.
Reading	51½° N.	1° W.
Southampton	51° N.	1½° W.
Warwick	52¼° N.	1½° W.
Yarmouth	52½° N.	1¾° E.

B. 16. Make a table showing the latitude and longitude of Liverpool, Manchester, Bristol, Birmingham, Newport, Stoke, Fishguard, Exeter, Buckingham, Ely, Swindon, Bodmin, Shrewsbury, Boston, Rhyl. (Use the map on page 50.)

For the angular measurement of latitude and longitude see page 199.

LONGITUDE AND TIME

All places on the same meridian have the same time, and it would be very convenient if we could do away with the word meridian and use " time line " instead. We might even use the term " same-time line."

An airman flying southward to the Gold Coast follows the Greenwich " time-line " all the way and his watch does not need altering. On the other hand, a ship going from England to New York crosses many meridians and the clocks have to be altered each day as a result.

A man with a wireless set who wishes to listen in to the eight o'clock concert from New York must sit up until 1 a.m., while if he wants to get the eight o'clock concert from Berlin he must tune in at seven.

HOURS AND DEGREES

The sun travels over the 360 meridians round the earth in 24 hours, that is 15° in one hour, or 1° in four minutes.

Since Reading is on meridian 1° W., the noon sun reaches it four minutes after passing the Greenwich meridian. Similarly, Liverpool on meridian 3° W. has noon twelve minutes after Greenwich. Formerly each town kept its own local time, but with the coming of telegrams and telephones and punctual trains this proved very inconvenient, and so now all Britain keeps Greenwich Time.

WHAT IS THE TIME IN NEW ORLEANS?

New Orleans is on meridian 90° W.

Being to the west of us, it has the sun after we do.

$$90° \div 15° = 6.$$

New Orleans time, then, is 6 hours behind ours, so that when it is 9 a.m. with us it is 3 a.m. there.

WHAT IS THE TIME IN CAIRO?

Cairo is on meridian 30° E.

$$30° \div 15° = 2.$$

Places to the east of us have the sun before we do; when, therefore, it is 9 a.m. in Britain it will be 11 a.m. in Cairo.

B. 17. What will be the time in Calcutta (90° E.) when it is 6 a.m. here?

B. 18. What will be the time in England when it is 12 noon at Shanghai (120° E.)?

B. 19. What will be the time in the Falkland Is. (60° W.) when it is 12 noon at Greenwich?

B. 20. Fiji is on the meridian 180°; what is the time there when it is 12 noon at Greenwich?

THE INTERNATIONAL DATE LINE

As meridian 180° does not pass through any important countries, lying as it does in the middle of the Pacific, it forms a convenient basis for the date or calendar line. Each new day begins on its western side and moves westward round the world. When a ship sailing westward crosses meridian 180°, not only is the clock altered but the day as well. In the map

there is a jump from 7 o'clock on Monday morning to 6 o'clock on Tuesday morning, the rest of Monday and the first part of Tuesday being lost. Going eastward across meridian 180° the change is from 5 a.m. on Tuesday back to 6 a.m. on Monday, so that the crew have Monday all over again. Ships on a westerly course therefore advance the date one day (e.g. March 31st to April 2nd), while ships on an easterly course double the day of crossing (e.g. December 24th, December 25th, December 25th, December 26th). The extra day is called Antipodes Day. The actual course of the date line is chosen so as to pass round any group of islands; otherwise neighbouring villages might have different dates.

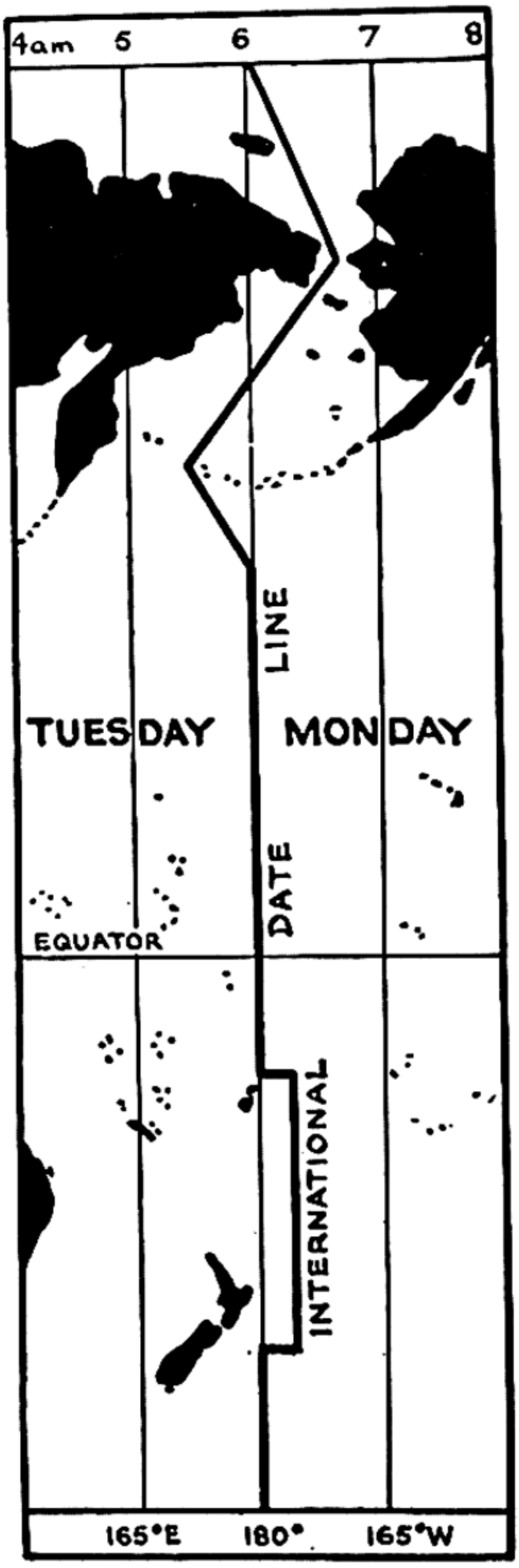


FIG. 73.—THE DATE LINE.

THE TIME BELTS

For the convenience of business men the clocks of all the important commercial countries of the world (except Holland) are set at an exact number of hours or half-hours before or after Greenwich in order to make the calculations quite simple. Thus New York is reckoned as five hours slower than Greenwich instead of 4 hours 56 minutes.

In Europe without Russia, there are three time belts: (1) Greenwich Time, (2) Mid-European Time, and (3) East

European Time. The Central meridians of the belt are 0°, 15° E., and 30° E.; their boundaries follow the state boundaries.

In European Russia clocks are set to the time of meridian 45° E.

In North America, which extends much farther from east to west, there are five zones: Atlantic, Eastern, Central,



FIG. 74.—THE TIME-ZONES OF EUROPE.

Mountain, and Pacific. They vary greatly in width and their boundaries are very irregular.

Tasmania, Victoria, New South Wales, and Queensland are 10 hours earlier than Greenwich, Western Australia 8 hours, South Australia 9½ hours, and New Zealand 11½ hours. All India, with the exception of Calcutta, is 5½ hours earlier.

ATLAS EXERCISES

C. 1. With the aid of Fig. 74 write the names of the countries of Europe using (*a*) Greenwich Time, (*b*) Mid-European Time, and (*c*) Eastern Europe Time.

C. 2. Calculate the times of the following places when it is 11 a.m. at Greenwich.

Auckland
Baghdad
Cape Town
Chicago
Denver
Iceland
Karachi
Mauritius
Montreal
Adelaide
Tokio
Rangoon
Bahamas
Vancouver (B.C.)
New York
Perth (W.A.)
Rio
San Francisco
Singapore
Sydney
Tangier
Winnipeg

GREENWICH MEAN TIME

We have three ways of telling the time—by the clock, by the stars, and by the sun. Of these the stars run quite regularly, the clock tries to run quite regularly but has to be put right occasionally, while the sun is very irregular. If a star is due south at 10 to-night by the clock, it will be due south at 4 minutes to 10 to-morrow night, 8 minutes to 10 the next night, 12 minutes the next, and so on ; in other words, it is 4 minutes earlier each succeeding night. With the sun, however, it is different. Sometimes it goes faster than the clock and sometimes slower. The two agree every Christmas Day and on three other days in the year, but while the sun moves sometimes faster and sometimes slower, the clock ticks out average or " mean " time steadily throughout the year. It was partly to find out what " mean " time should be that Greenwich Observatory was founded in the reign of Charles II, on a hill overlooking the Thames just below London.

The times by the clock when the sun is in the south are given on page 190.

Greenwich Mean Time (G.M.T.) is now the standard time for the world.

NOON

In ordinary language noon is midday, and we speak of 12 o'clock noon or 12 o'clock midday.

At sea a sailor finds noon for the position of his ship by watching the distance between the horizon and the sun with a sextant, an instrument that measures such distances to a small fraction of a degree. The moment at which the sun reaches its highest point is noon.

When it is noon at Greenwich the sun is overhead somewhere on the Greenwich Meridian, it may be on the Equator, or it may be at any other point between the two tropics.

For us in Britain the sun is always in the south at noon.

Since the introduction of "summer time" noon, according to the clock, varies greatly from one part of the year to another. At the beginning of August, for instance, it is at 1.6 p.m., while at the end of October it is at 11.44 a.m.

THE LATITUDE AND LONGITUDE OF THE SCHOOL

Draw a north-south line on the floor. This is the meridian of the school. If you could carry it northward one way and southward the other way to the poles it would be just like the meridians on the globe. Similarly, if a string could be stretched on the Earth itself from the north pole to the south pole, passing through your school, the piece lying across the floor would appear merely as a north-south line.

Draw a line at right angles to it. This is the parallel of latitude. The numbers of these two lines in degrees and minutes may be judged approximately from an atlas or obtained by reference to the Ordnance map (see page 143).

TO CALCULATE LOCAL NOON IN YOUR OWN TOWN

(1) Find the time when the sun is in the south at Greenwich.

(2) Find from the map on page 50 how much earlier or later the sun reaches you each day compared with Greenwich.

(3) Proceed as in the following example.

Example: On October 26th, a Liverpool man wishes to know when the sun is due south of him. By the table on page 190 the sun is south at Greenwich at 11.44. According to the map it is south at Liverpool twelve minutes later, i.e. at 11.56.

TO DRAW A NORTH-SOUTH LINE BY THE SUN

Find when the sun is due south in your town to-day and mark out on the floor the shadow of a vertical line such as the edge of a window frame. This can best be done by pinning one end of a piece of string to the floor, about a minute beforehand and then holding it parallel to the edge of the shadow. Precisely at noon, fix your end and draw the line.

THE DIVISIONS OF A DEGREE—MINUTES, SECONDS, AND CABLES

A degree is divided into sixty minutes, and each minute is further divided into sixty seconds (minutes of arc and seconds of arc).

The average degree of latitude [1] is 60 sea miles (or nautical miles).

A minute of latitude is therefore 1 sea mile. This is about 6,000 feet, the exact number varying from one country to another.

A second of latitude is 100 feet, and if a playground is large enough it is possible to draw two parallel east and west lines in it a hundred feet away from each other, which will be two lines of latitude one second apart.

A " cable " that we so often read about in sailing-ship days is 600 feet (100 fathoms), or one-tenth of a minute of latitude.

[1] As the Earth is not quite a sphere a degree of latitude near the pole is longer than one at the Equator (see table on page 192).

THE KNOT

In the shipping world a speed of 1 nautical mile or 1 minute of latitude per hour is called a knot.

$$\text{One nautical mile} = \frac{70 \text{ statute miles}}{60} = 1\tfrac{1}{6} \text{ statute miles.}$$

A vessel making twelve knots is therefore moving at $12 \times 1\frac{1}{6}$ or 14 miles per hour.

USING THE ATLAS

In atlases latitude and longitude are frequently given in *degrees* and *minutes*, e.g.

Bremen 53 4 N. 8 47 E.

This reads 53 degrees 4 minutes North latitude,
8 degrees 47 minutes East longitude.

or Lat. 53° 4′ North ; Long. 8° 47′ East.

For most purposes we can read the nearest degree, so that Bremen is in latitude 53° N. and longitude 9° E.

GREAT CIRCLES AND SMALL CIRCLES

If the globe in Fig. 63 were cut in two through the equator, the cut would pass through its centre and we should find that the globe centre and the centre of the equator circle are the same. But if the cut were made through parallel 30° N., the circle would be smaller than the equator and its centre would not be the centre of the globe. The same thing would occur if the cut were made through any other parallel.

All circles on the globe having their centres the same as the globe centre are great circles, no matter in which direction they lie. The others are small circles.

The equator, then, is a great circle and all the other parallels small circles. The meridians are halves of great circles.

An Experiment

On a tennis ball draw a great circle for the Equator and two dots for the poles. Hold the ball up in a strong light. Notice

that " day " and " night " divide the ball equally and that the line separating them is a great circle.

Turn the ball first so that the dividing line falls along the equator, then so that it passes through the poles forming two meridians.

Now hold it in a number of positions and notice that the dividing line always cuts the equator into two equal parts (except, of course, when it lies along it).

PLANE SAILING AND GREAT CIRCLE SAILING

On a long journey across the ocean a ship's captain has to take the curvature of the Earth into account and find the shortest routes. In former times some very difficult calculations had to be made for this. On a short journey, however, of only a few hundred miles, as in the North Sea or the Irish Sea, he can assume that the Earth has a flat or " plane " surface. This is when he speaks of " plane sailing," and the work in laying his course is very simple indeed.

The shortest distance between the two places on the globe always lies along a great circle. This can be tested on the school globe by stretching a piece of string from pole to pole so that it passes through London. It will always follow the meridian, and no shorter way can be found. Or if the string be stretched between two places on the equator, the equator itself will prove to be the shortest distance between the two points.

B. 21. On the globe in Fig. 63, the great circle route between New York and Rome is marked by a dotted line : (*a*) in which direction will an aeroplane start from New York to go to Rome, and (*b*) in which direction will it finish its journey ?

QUESTIONS ON CHAPTER FIVE

A. 1. What do we mean by latitude ?
A. 2. Why are lines of latitude called parallels ?
A. 3. What are the boundaries of the North Temperate Zone ? What determines where these boundaries fall ?

A. 4. How is it that Gibraltar and the Gold Coast keep Greenwich Mean Time while New York and Cairo do not ?

B. 1. How is the area of the surface of a sphere calculated ? Assuming that the Earth's diameter is 8,000 miles, work out its surface area.

B. 2. How is the position of a ship described at sea ? Give a concrete example and explain it.

B. 3. How is a degree of latitude sub-divided ?

C. 1. How are a "knot" and a "cable" related to the size of the Earth ?

A. 5. What is meant by the longitude of a place ?

B. 4. What is the relationship between longitude and miles ?

B. 5. What is the International Date Line ?

C. 2. What is meant by Greenwich Mean Time ?

C. 3. In what way does a great circle differ from a small circle ?

Chapter Six

EARTH, SUN, AND MOON

HERE are four statements that are all true enough to begin with, though none of them is quite correct when we enquire more closely :

(1) The earth rotates upon its axis once in 24 hours, giving us day and night.

(2) The earth revolves round the sun once a year. This revolution results in our changing seasons.

(3) The moon goes round the earth once a month, the movement being connected with the tides.

(4) The stars and sun do not move.

We can " feel " all the three movements if we know how to look at the sky and experience each one separately. Our great difficulty is that the Earth, which has two movements, one about its axis and one round the sun, seems to us to be perfectly still, while the stars and the sun, although they are " fixed," seem to be moving.

In the exercises that follow we shall observe the movements thus :

Rotation of the Earth by watching a shadow.

Revolution of the moon by watching (1) the moon and a star, (2) the moon and sun.

Revolution of the Earth by watching a star and a building.

THE ROTATION OF THE EARTH

Stick a pin upright in a ball, rotate the ball in the sun and notice how the shadow of the pin moves over its surface. Now watch a shadow on the floor closely and try to think that

it is the Earth that is moving. That may not seem very interesting at first, but it is very important and may prove very fascinating after a time.

THE REVOLUTION OF THE MOON

It is possible to see the moon move a part of its way round the Earth by watching it for one evening only. Notice its distance from a star as soon as it gets dark and again an hour later. The distance will by then have altered. It will be found that the moon has moved to the left (as we see it in Britain) about its own diameter. This can best be understood from the diagram (Fig. 75).

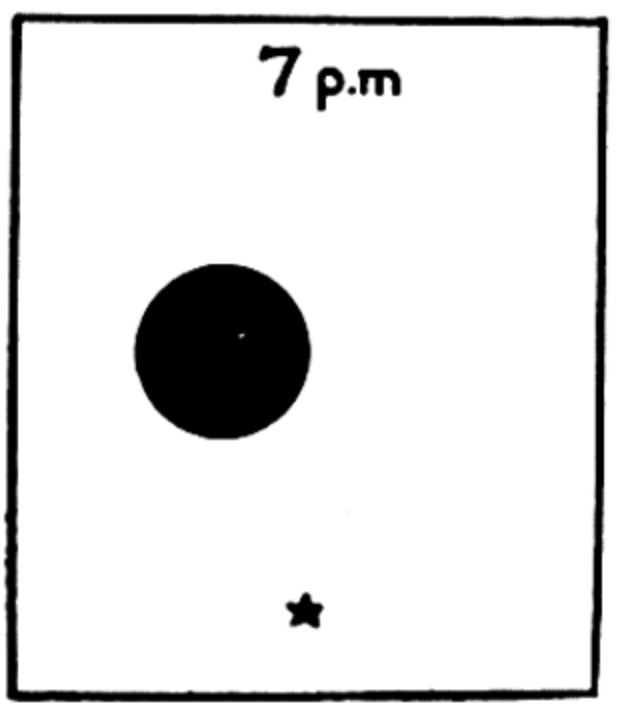


FIG. 75. — THE MOON PASSES A STAR.

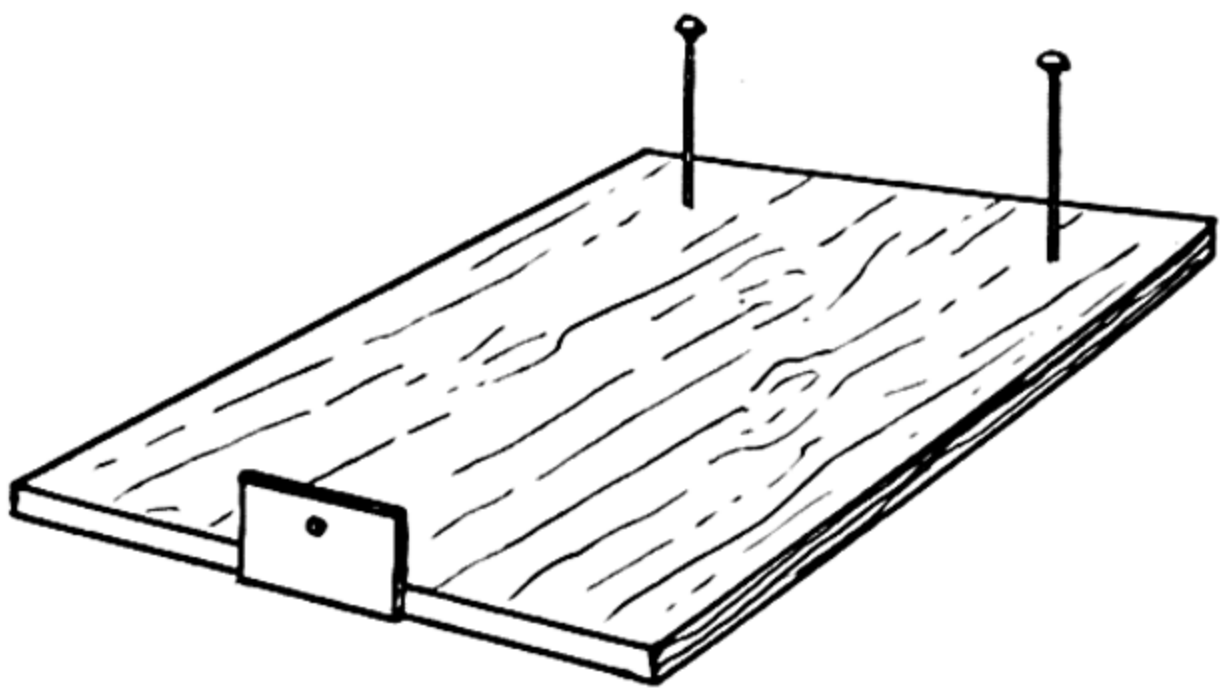


FIG. 76. — APPARATUS FOR WATCHING THE MOON APPROACH A STAR.

EXPERIMENT 1

When, as will frequently happen, the moon is not close enough to the star for the movement to be measured with the eye, make the piece of apparatus in Fig. 76. The base is a piece of wood ; a piece of card is pinned to one end and two pins are fixed at the other. In the card is a small hole. Look through this and hold the board so that one pin is on the moon, then shift the other until it is on the star. At the end of an hour test the distance again.

EXPERIMENT 2

There is also a way of watching the revolution of the moon in the daytime. When you can see the sun and the moon in the sky at the

same time, point to the sun with the right hand and to the moon with the left and notice the distance between your two hands. Repeat the experiment on the following days and see what happens. (With the morning moon the positions are reversed.)

DIAGRAMS—A WARNING

To understand fully the movements of the Earth and moon we need a number of diagrams, but unless such diagrams are



FIG. 77.—THE MOON REVOLVING ROUND THE EARTH, AND THE EARTH REVOLVING ROUND THE SUN.
The relative sizes and distances are incorrect.

used very carefully they are apt to lead to very erroneous ideas. Suppose, for instance, we consider the one in Fig. 77. The circle marked S is the sun, the tiny circle is the Earth, and



FIG. 78.—THE EARTH AND THE MOON AND THE DISTANCE BETWEEN THEM DRAWN TO SCALE.

the dot the moon, the large dotted arrow shows the movement of the Earth round the sun, the small one shows the revolution of the moon round the Earth.

In one way the diagram is quite a good one, but if we decide to draw it to scale with the sun as our standard, the Earth will be only 1/200th of an inch in diameter and will be nearly five feet away.

If, however, we take the Earth as correct, and we could hardly make it smaller, the sun will be more than a foot wide and close on forty yards away. The distance between the moon and the Earth will then be $3\frac{3}{4}$ inches (Fig. 78).

THE MOON GOES ROUND THE EARTH

It is because the moon revolves round the Earth that we have full moon and half moon, and that while sometimes the moon shines brightly at night there are times when it does not appear at all.

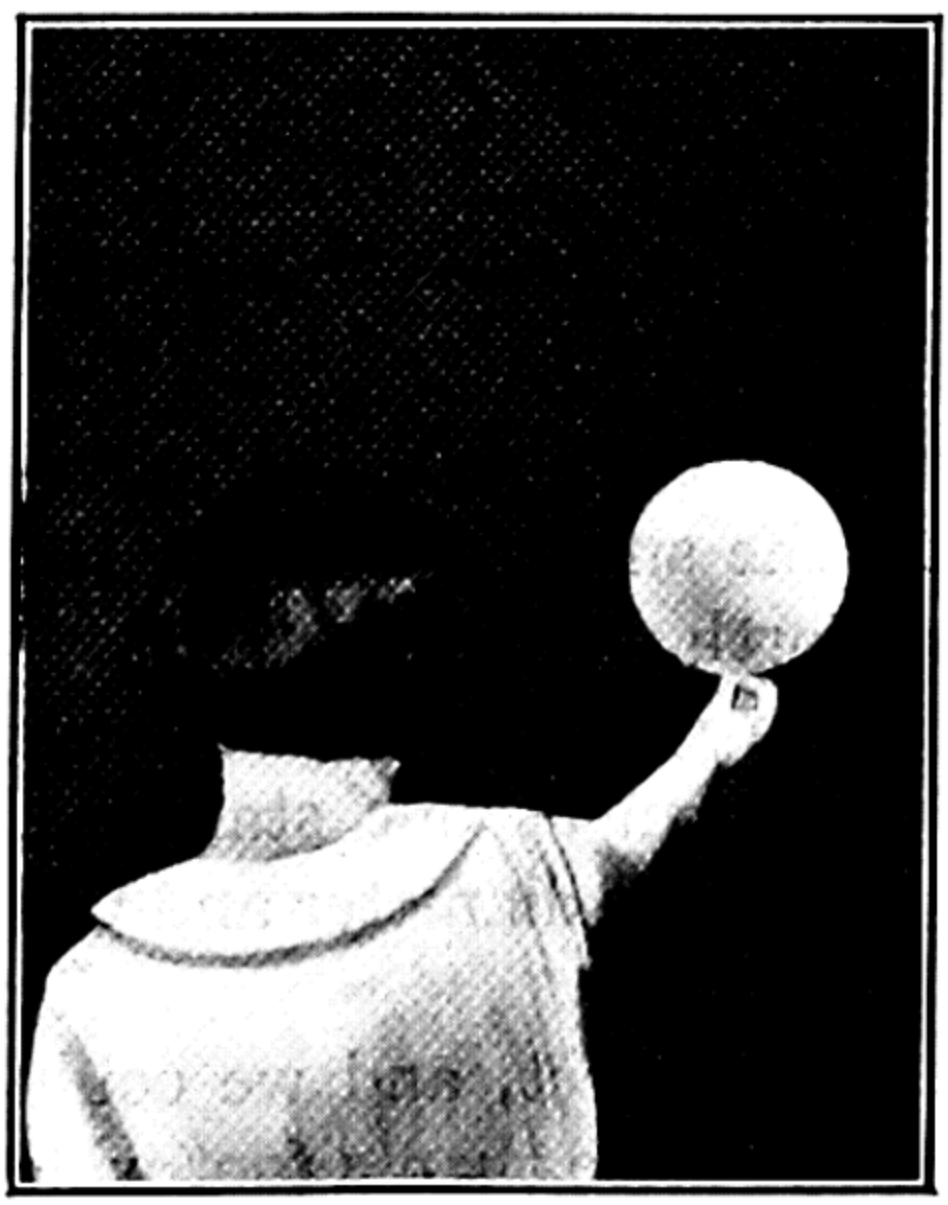
EXPERIMENT 3

On an occasion when the sun and moon are in the sky at the same time, stand in the sunshine, hold a white ball up at arm's length in such a position that its edge appears to you to touch the edge of the moon. Or, better still, let a friend hold the ball in this position for you, about ten feet away. The part of the ball that you can see lit up by the sun will be the same shape as the moon. If, for instance, the experiment is carried out late in the afternoon when the crescent moon is curved towards the setting sun, the light on the ball will appear as a crescent also, curving towards the sun.

THE PHASES OF THE MOON

EXPERIMENT 4

Here is an experiment that will help us to understand how the various " phases " of the moon (new moon, half moon, full moon, etc.) are brought about. It can be carried out either in the open when the sun is low in the sky, or indoors with the light of an ordinary candle or lamp. It gives the best result when the light is about on a level with the eye.



[*Photo by S. Wyles.*

FIG. 79.—THE EARTH LOOKS AT A FULL MOON.

Stand with your back to the light and hold the ball at arm's length. The ball represents the moon and you are the Earth. In this position the "earth" sees a full moon. Turn slowly to the left, carrying the ball round with you, and notice

that the lit-up part gets smaller until only half of it can be seen.

Continue turning until none of the lit-up part is visible.

Next turn very slightly until a thin line appears on the right edge of the ball. This is the new moon.

Complete the turn, passing the half-moon position and arriving at full moon again.[1]

It sometimes happens that as the full moon is rising on one side of the sky the sun is setting on the other (or vice versa). That is the best time to see the Earth, sun, and moon themselves in line with one another.

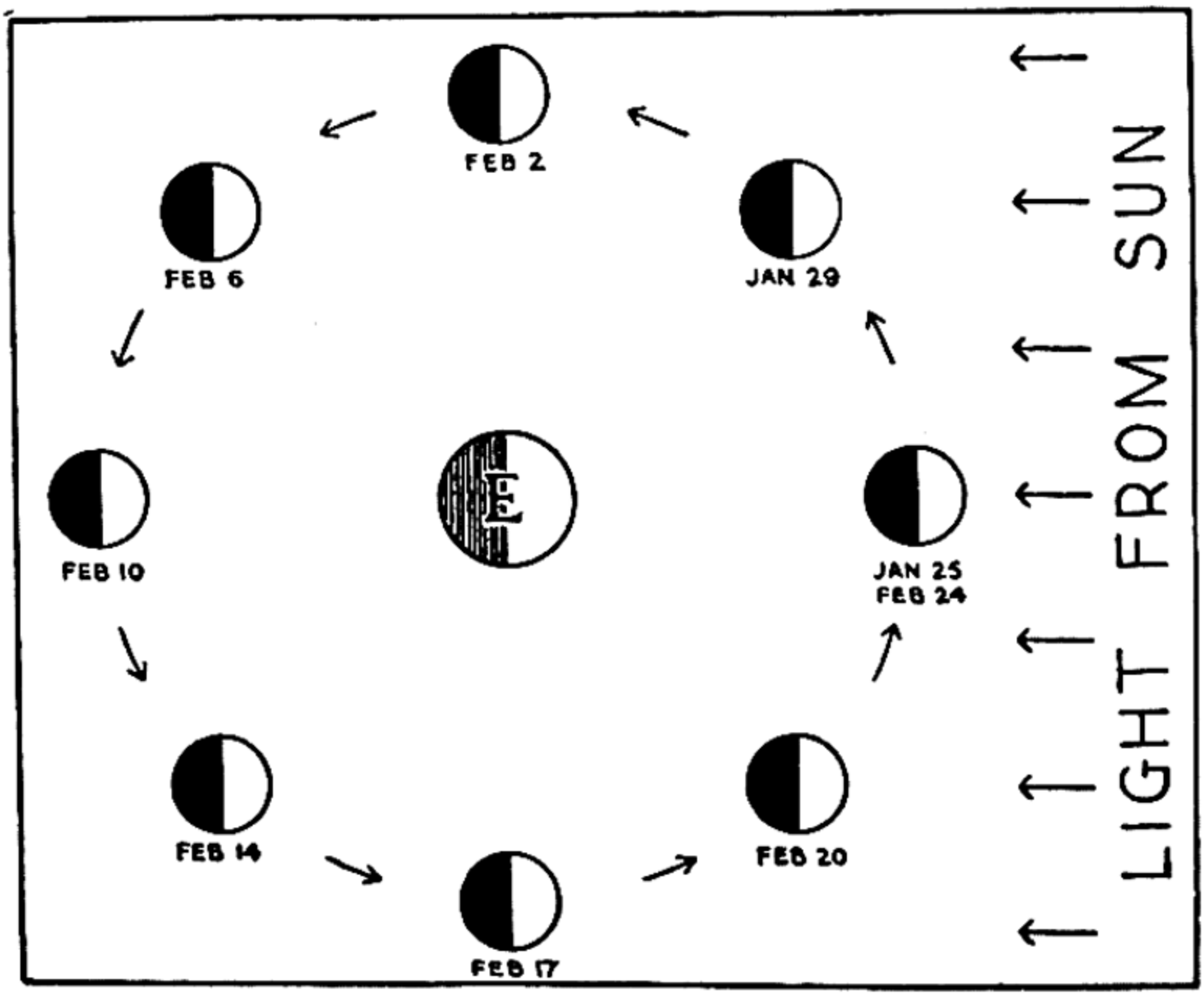


FIG. 80.—A MONTH OR A "MOONTH."

The revolution of the moon is put in diagram form in Fig. 80.

Imagine yourself standing on E, the Earth, looking at the moon on February 10th. It will appear full. On the 24th, as

[1] Notice that if the Earth and moon are kept strictly in line there is an eclipse of the moon at the full and an eclipse of the sun at new moon.

only the dark side is turned towards the Earth, it will not be visible at all, while on the 2nd and 17th it will be "half."

The phases are given in order in the next diagram.

Notice that the full moon shines all night. The new moon shines all day, though we seldom see it except at sunset.



FIG. 81.—THE PHASES OF THE MOON.

First Quarter, February 2nd; Second Quarter, February 10th; Last Quarter, February 17th.

A. 1. How long is it from one full moon to the next?
A. 2. How long is it from full moon to "no" moon?
B. 1. When are the sun, Earth, and moon in a straight line?
B. 2. When do the lines joining them make a right angle? Draw a diagram to illustrate your answer.
C. 1. Copy the diagram of the phases of the moon, adding dates for the present moon. These can be obtained from a pocket calendar or *Whitaker's Almanack*.

WATCHING THE REVOLUTION OF THE EARTH

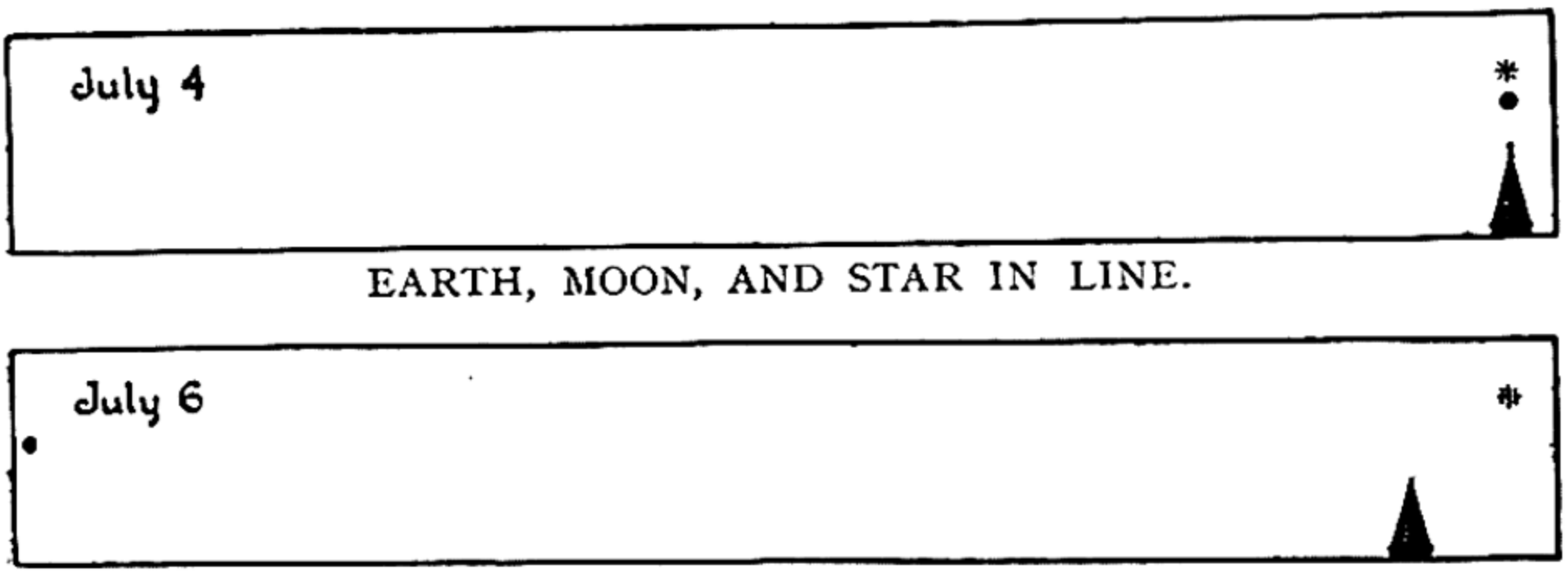
Because the Earth is always rotating we have some difficulty in actually seeing the revolutions of the Earth and moon, just as a man sitting on a moving roundabout at a country fair cannot tell which way any particular person among the spectators is moving, because all of them seem to go whirling past him together. Yet we can get over the difficulty if we look at the southern sky for a minute or two only each night, or as often as possible, provided we do it at exactly the same time by the clock.

It is important to remember that the stars do not move.

On July 4th at 10 p.m. the moon and a star appeared immediately over the spire of a church, but to begin with we will

consider only the star. On July 6th at 10 p.m. it appeared at first sight as though it had moved a little to the right of the spire. Since, however, stars do not move, it must have been in the same place as before. What had happened was that the Earth had moved a little to the left on its way round the sun. By August 2nd at 10 p.m. the Earth had moved quite a long way to the left.

The moon was close to the star on July 4th, but by the 6th had moved a long way to the left on its journey round the Earth. By August 2nd it had almost completed the journey.



EARTH, MOON, AND STAR IN LINE.

EARTH HAS MOVED A LITTLE WAY ROUND THE SUN. MOON HAS MOVED A LONG WAY ROUND THE EARTH.

EARTH HAS MOVED A LONG WAY ROUND THE SUN. MOON HAS BEEN RIGHT ROUND THE EARTH

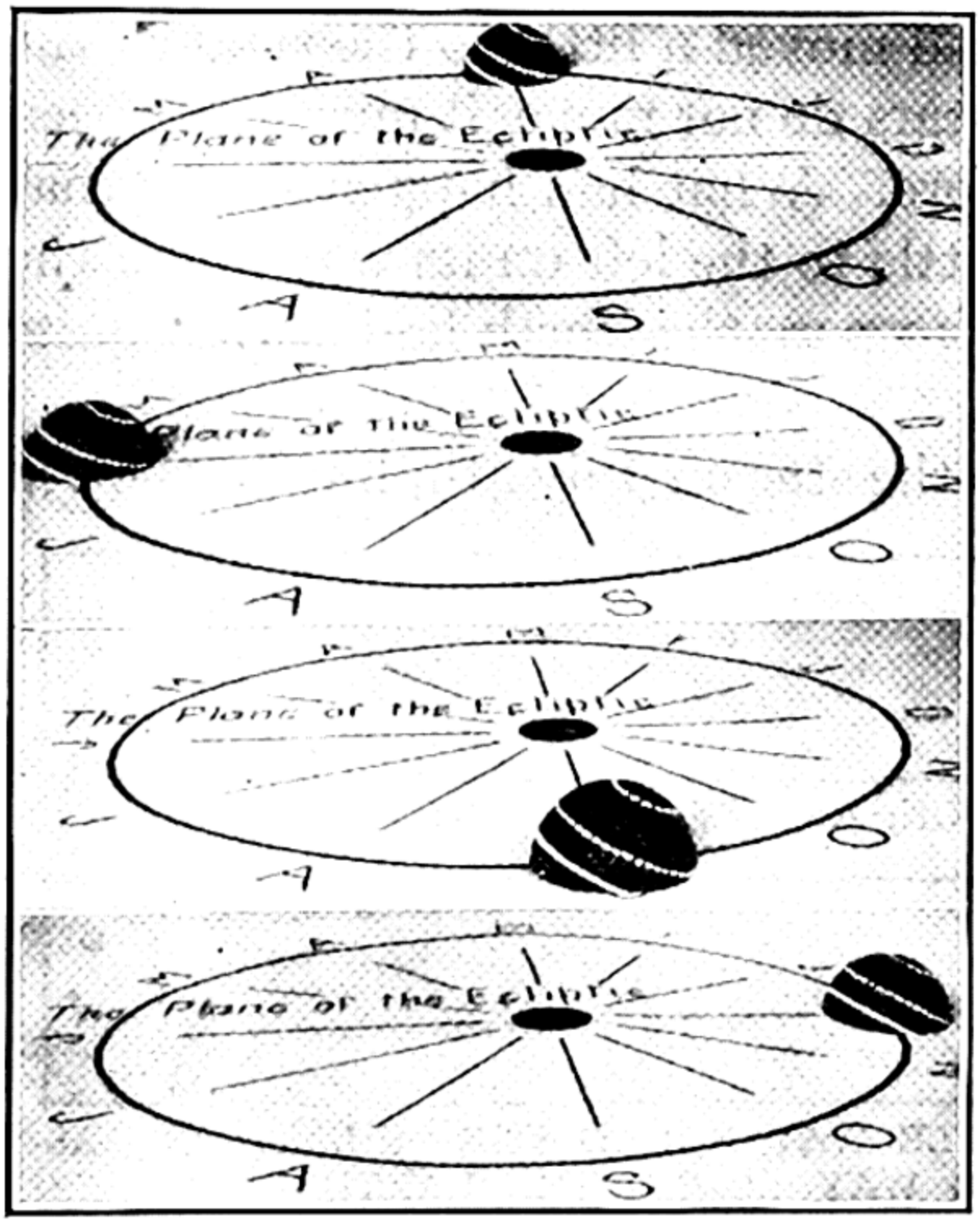
PATHS OF THE EARTH AND MOON DURING ONE MONTH.

FIG. 82.

The bottom diagram shows the Earth moving along its orbit with the moon revolving round it.

D. 1. With the aid of a sketch and a diagram, explain how the revolution of the Earth round the sun can be watched.

THE UNEQUAL SEASONS



[*Photo by E. J. O.*

FIG. 83.—IF THE MARCH "EARTH" IS ROTATED THE LINE FROM THE SUN WILL ALWAYS TOUCH THE EQUATOR.

In March the sun is overhead on the Equator.

In June it is on the northern tropic. The northern hemisphere has summer.

In September the sun is again on the Equator.

In December it is overhead on Capricorn. The northern hemisphere has winter.

If we count up the days for the period March 21st to September 23rd, when the sun is north of the Equator, and then from September 24th to March 20th, when it is south, we shall find that they are unequal, the southern period being some days shorter. This is because in December the Earth, being closer to the sun than it is in June, travels faster: it therefore covers the December half of its course in less than half a year.

B. 3. With the aid of a calendar find how much longer the sun is to the north of the Equator than it is to the south.

ORBIT AND ECLIPTIC

The path of the Earth round the sun is called its orbit. The plane in which it lies is the ecliptic, so named because during an eclipse the Earth, sun, and moon all lie in it.

The inclination of the Earth's axis to the plane of the ecliptic is 66½°. This is the angle at which globes are usually mounted. The "top" point is then on the Arctic Circle and the "bottom" point on the Antarctic Circle.

The effect of the revolution of the Earth with its axis always inclined at this angle is to make the position of the overhead sun move from one tropic to the other and back, crossing the Equator twice during the year, in March and September. Generally the dates are March 21st and September 24th.

Fig. 84 helps us to understand why in Britain December days

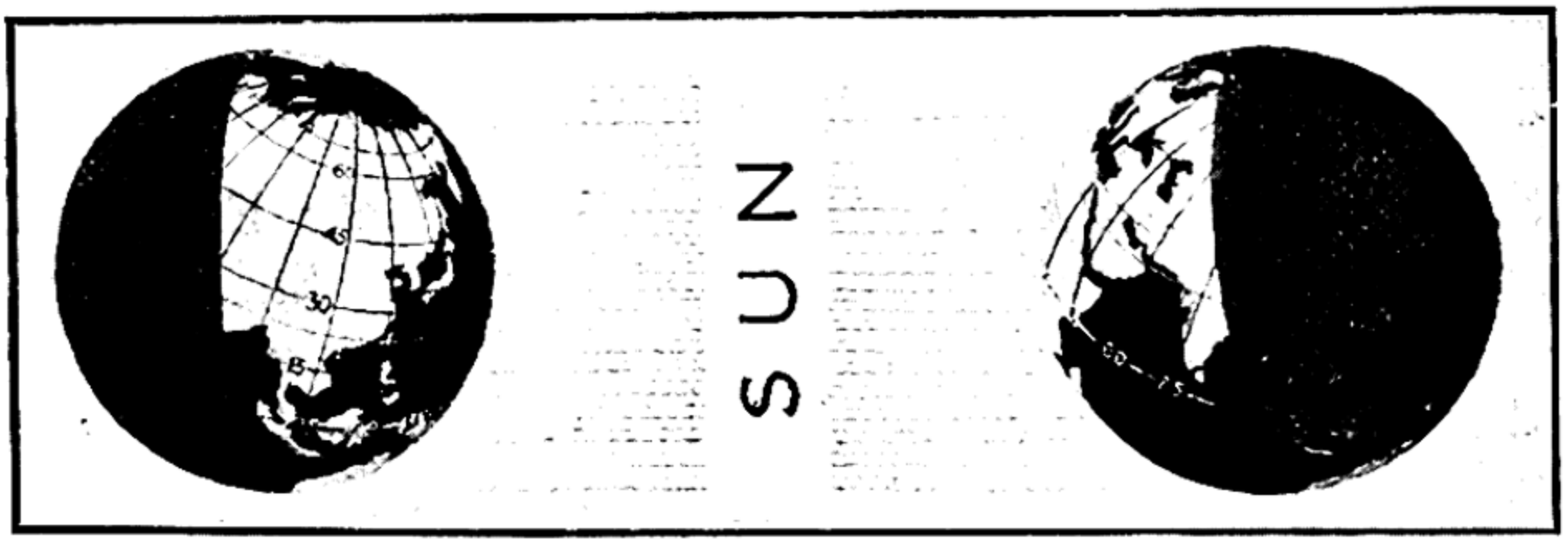


FIG. 84.

are short and June days long. To understand it fully it is necessary to think of the Earth as turning eastward all the time.

In June the sun is just rising on the Equator at meridian 90° E. On parallel 30° N. it is rising an hour earlier, and, since it will set an hour later, the day there will be two hours longer than the day on the Equator. In other words, Midsummer Day on parallel 30° N. will be 14 hours long.

Work out the lengths of Midsummer Day on parallels 45° and 60°, and compare your results with the table on page 75.

The length of Midwinter Day on each parallel should be worked out similarly.

THE SOLSTICES

For some days before and after Midsummer Day the sun rises at the same time and in the same direction as far as an

ordinary person can see, and it sets at the same time each evening and in the same direction. At noon, too, each day it reaches the same height.

This is the time of the Summer Solstice—the time when the sun " stands still."

Before and after December 21st the sun " stands still " again. This is the Winter Solstice.

Try to remember to watch where the sun rises each morning for the week preceding Christmas Day, and where it sets for the week preceding St. John the Baptist's Day (June 24th).

THE EQUINOXES

Since all its nights are the same length, the Equator is sometimes called the " Equinoctial Line " or line of equal nights. When the sun is overhead on the Equator in March and September we have the Vernal and Autumnal Equinoxes.

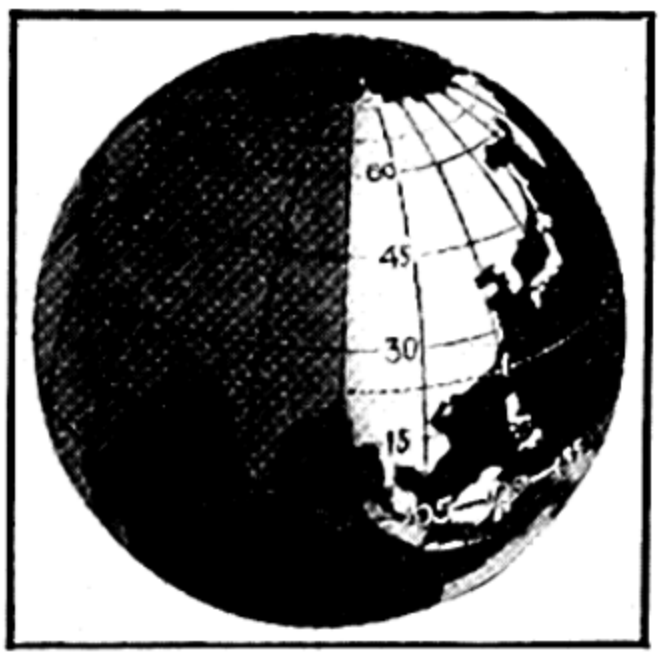


FIG. 85.

At the equinoxes the sunrise line falls along a meridian so that in all latitudes sunrise is at the same time as on the Equator, and the day is the same length everywhere (Fig. 85).

If the Earth had no atmosphere, the length of daylight on the Equator would be exactly twelve hours, but on account of the refraction due to the atmosphere the sun can be seen when it is just below the horizon. This makes sunrise about $2\frac{1}{2}$ minutes earlier than it would be otherwise, and sunset the same amount later. Then as sunrise is reckoned from the time the " top " of the disc appears on the horizon instead of the centre, it is a minute earlier still, making $3\frac{1}{2}$ minutes in all. Similarly, sunset is delayed $3\frac{1}{2}$ minutes altogether, and the twelve-hour day of the Equator is consequently lengthened to 12 hours 7 minutes.

LENGTH OF DAYLIGHT IN NORTHERN HEMISPHERE
21st of each month (1933)

Lat.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
0	12 7	12 7	12 7	12 7	12 7	12 7	12 7	12 6	12 6	12 6	12 8	12 8
10	11 38	11 52	12 7	12 24	12 37	12 43	12 38	12 24	12 8	11 51	11 38	11 32
20	11 7	11 36	12 7	12 42	13 9	13 21	13 10	12 44	12 10	11 36	11 7	10 56
30	10 31	11 18	12 8	13 2	13 46	14 5	13 48	13 6	12 12	11 18	10 32	10 12
40	9 48	10 56	12 9	13 30	14 33	15 1	14 36	13 33	12 14	10 57	9 49	9 20
50	8 47	10 27	12 12	14 6	15 39	16 23	15 44	14 11	12 18	10 28	8 42	8 4
55	8 04	10 7	12 13	14 31	16 28	17 18	16 34	14 37	12 21	10 8	8 5	7 35
60	7 06	9 43	12 14	15 3	17 34	18 53	17 43	15 11	12 25	9 43	7 9	5 52

THE LONGEST DAY[1] WITHIN THE ARCTIC CIRCLE

66½° N.	. 24 hours	80° N. .	. 134 days
70° N. .	. 65 days	90° N. .	. 6 months

LENGTH OF DAYLIGHT

The diagram shows the varying lengths of day and night throughout the year at Penzance (Lat. 50° N.). The positions of the points on the dividing line should be compared with the figures in the table. In December the day is 8 hours long, while in June it is 16⅔ hours.

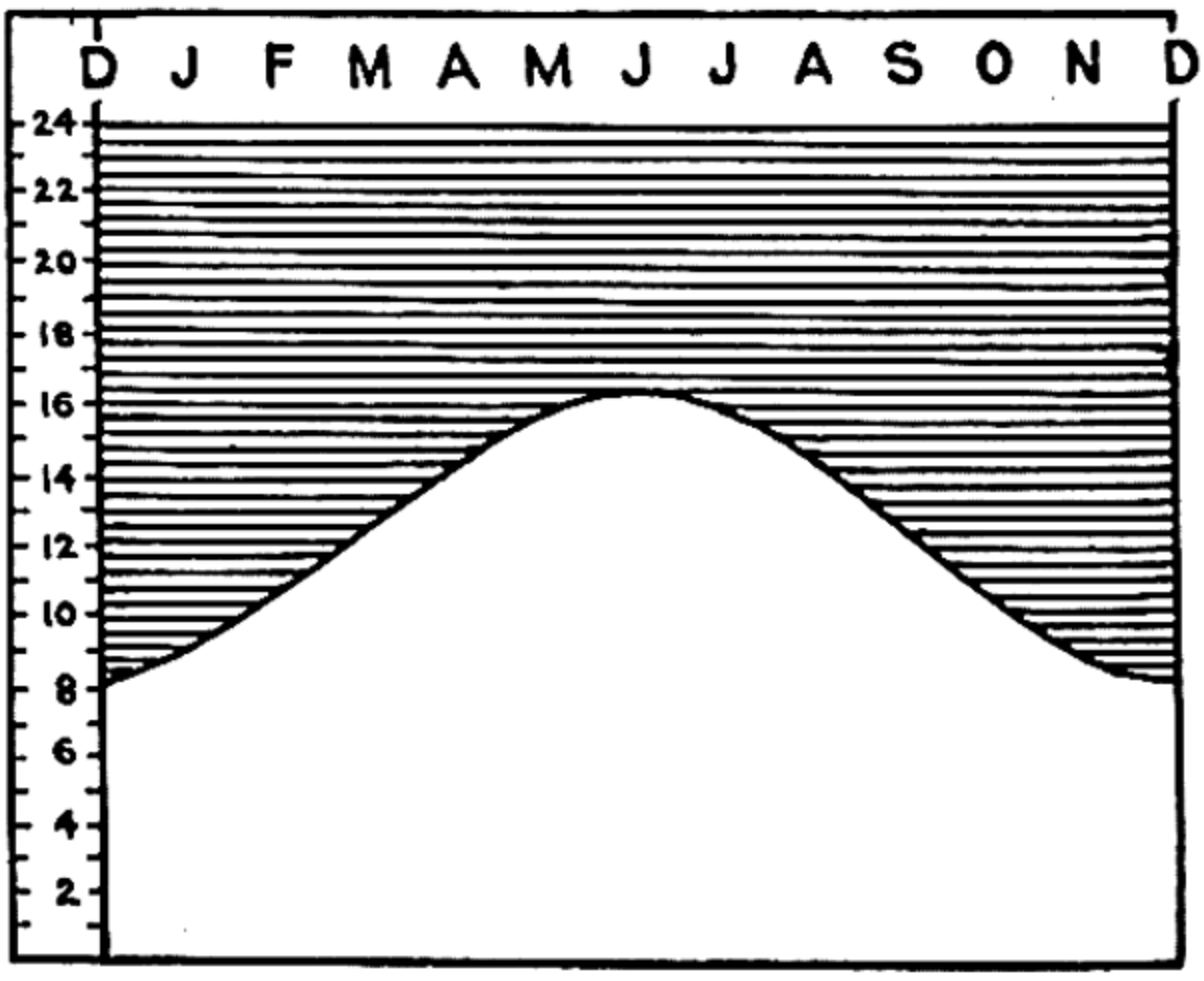


FIG. 86.—DAY AND NIGHT AT PENZANCE.

B. 4. Make a table showing the lengths of the longest and shortest days on each parallel with the difference between the two, e.g. Parallel 40°, longest 15 h. 1 m., shortest 9 h. 20 m., diff. 5 h. 41 m.

C. 2. Draw graphs to show the length of daylight throughout the year at: (*a*) Shanghai (30° N.), (*b*) Stockholm (60° N.), (*c*) Singapore (Lat. 0°), (*d*) S. Shields (55° N.).

FINDING THE LATITUDE OF THE SCHOOL EXPERIMENTALLY

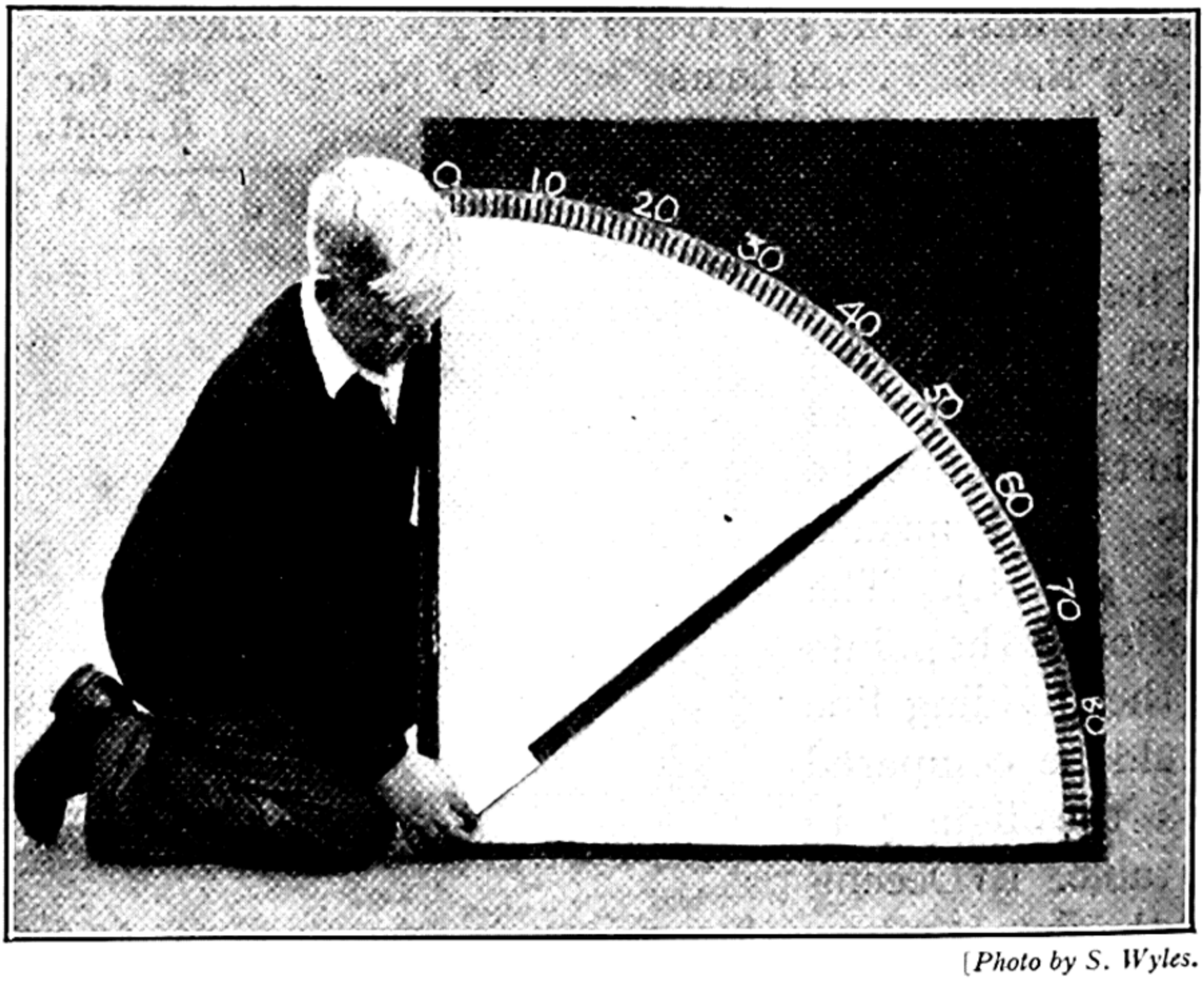
Imagine yourself looking at the sun at noon. If you could be whisked instantaneously to the spot where it is overhead, how many degrees of latitude would you have to travel?

[1] South of the Equator these numbers give the length of the night.

The answer is easily obtained. Find the number of degrees the sun is from your zenith or overhead point in the sky. This is called the "zenith distance" and is the number of degrees of latitude required.

THE QUADRANT

For making the measurement a quadrant is necessary, and one form of this instrument can be seen in Fig. 87.

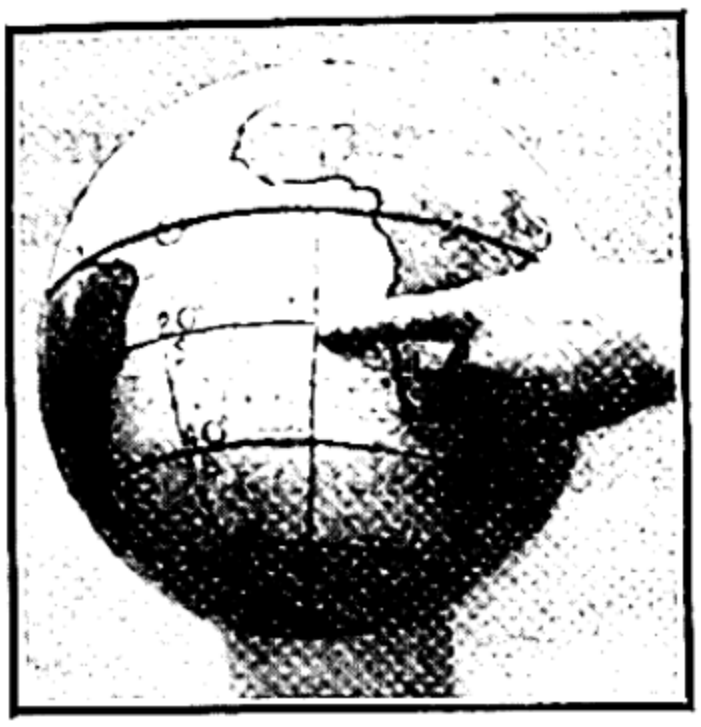


[*Photo by S. Wyles.*

FIG. 87.—THE SUN IS 52° FROM THE ZENITH OR OVERHEAD POINT.

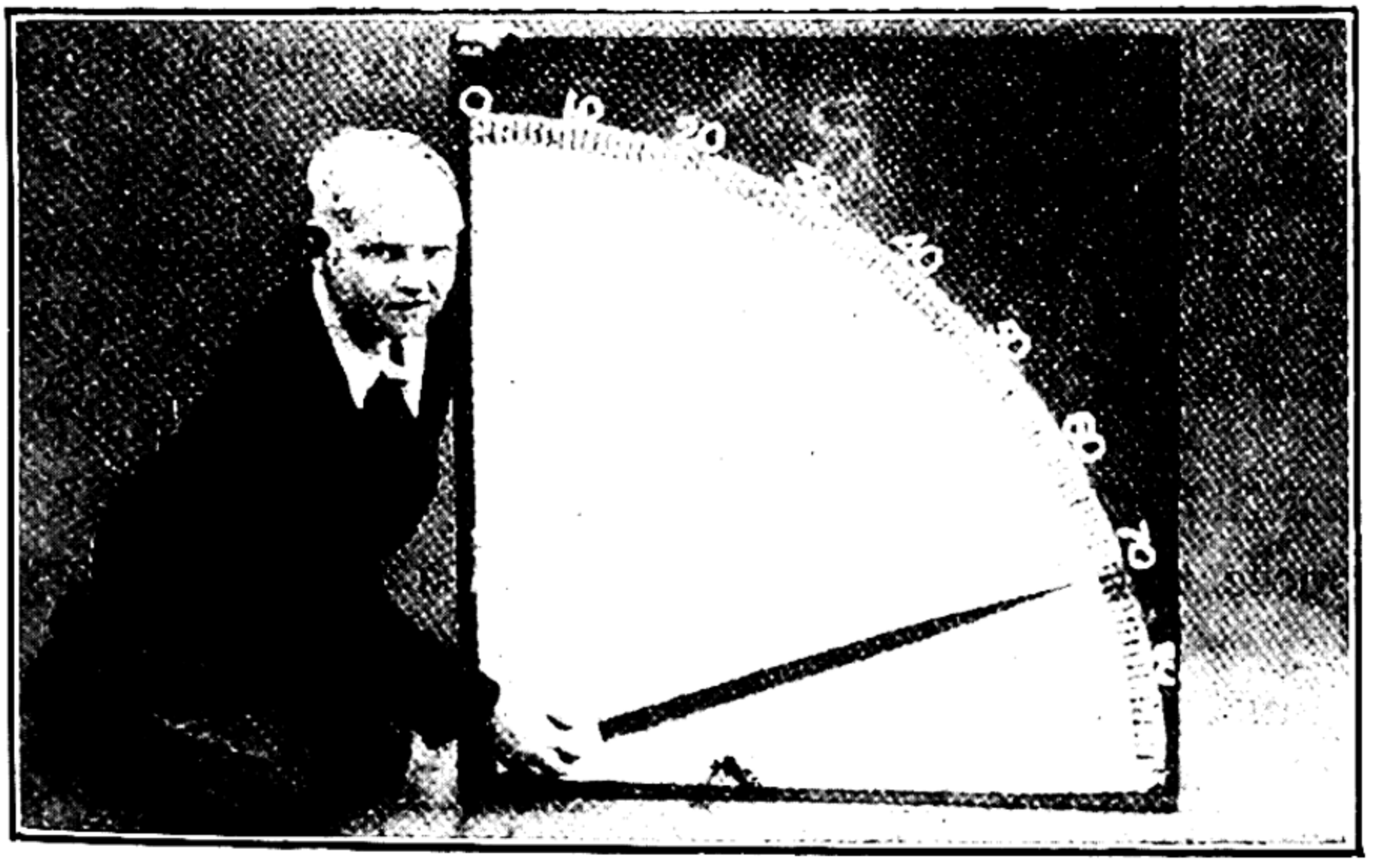
On March 31st a man somewhere in Britain finds with the aid of a quadrant that the noon sun is 52° from the zenith. What is his latitude?

Let us suppose that he is on meridian 5° W. We draw that meridian on the globe and on it put a mark at 4° N., the latitude of the overhead sun (see the declination table on page 197). If we measure 54° along the meridian from this point in the direction of Britain we shall come to parallel 56° N., which is the required latitude.



CHECKING THE LATITUDE OF LONDON

On one November 21st, the meridian of London was marked out plainly on the globe, and the almanack was consulted to find the latitude of the overhead sun. This proved to be 20° S. (see Declination of the Sun, page 197).



At noon the sun was found to be 71½° from the zenith.



[*Photos by S. Wyles.*

The distance along the meridian between parallel 20° S. and London was found to be 71½°; in other words, London was 51½° north of the Equator. This is the correct latitude.

Check the latitude of your school by the above method.

FINDING LATITUDE AT SEA

At sea a ship's captain gets his latitude in exactly the same way, though with much greater accuracy. He first finds at ship's noon how many degrees he is from the place where the sun is overhead. For this he uses a sextant where here we have to use a quadrant. He then refers to the almanack for the latitude of the overhead sun.

Example: (1) Date, June 21st.

Zenith distance of sun, 10° to the north.

That is, the sun is overhead 10° northward. From the almanack the sun is overhead on Cancer. He must therefore be on parallel 13½° N.

(2) Date April 22nd.

Zenith distance of sun 15° to the north. That is, the sun is overhead 15° northward. From the calendar the sun is overhead on 12° N. The ship is therefore on parallel 3° S.

WHERE IS THE SUN OVERHEAD AT THIS MINUTE?

Suppose that "this minute" is 10.20 a.m. on February 19th.

We must first find along what parallel of latitude the sun

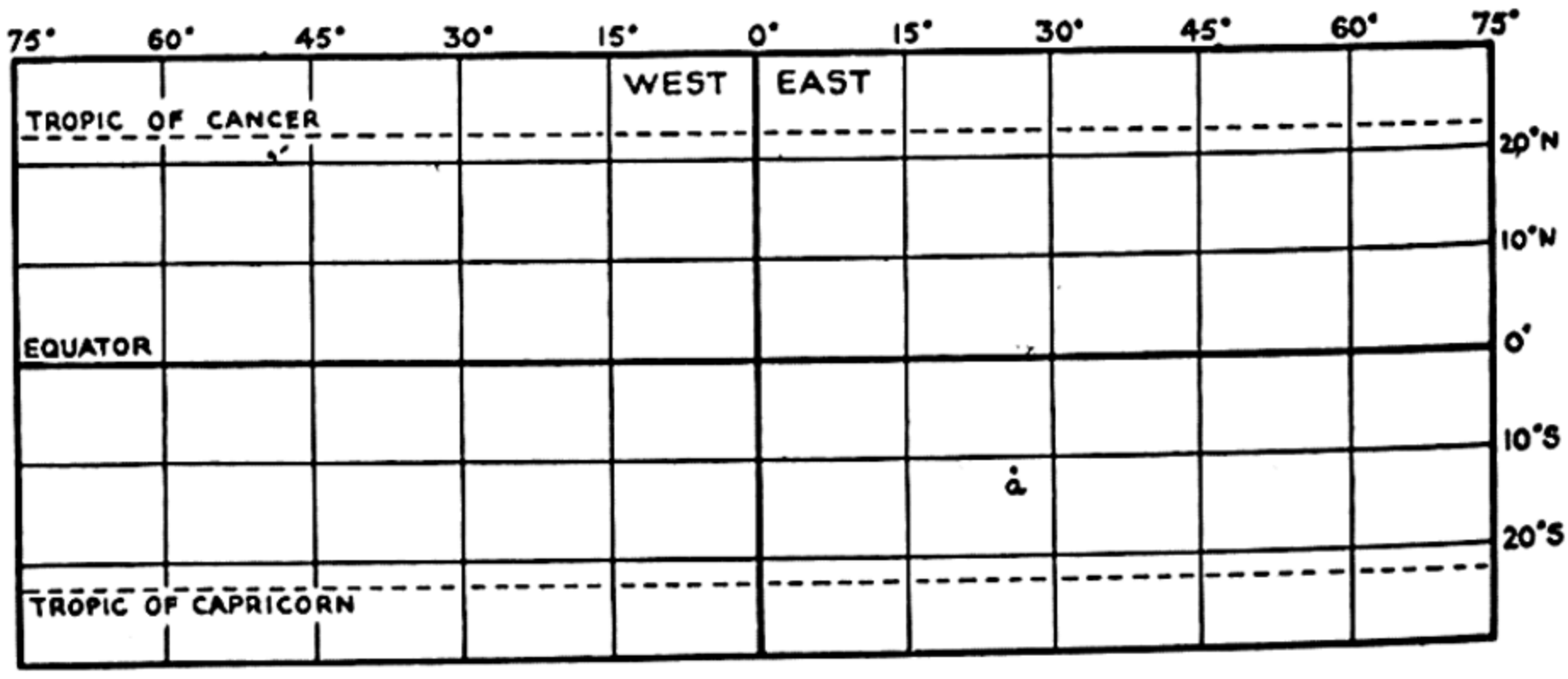


FIG. 88.

is moving on February 19th, and secondly how long it is from "this minute" till noon.

From the table on page 197 the sun is on parallel 11½° S.

From the table on page 190 noon is at 12.14.

Between now and noon is 1 hr. 44 mins., which is equal to 26° of longitude.

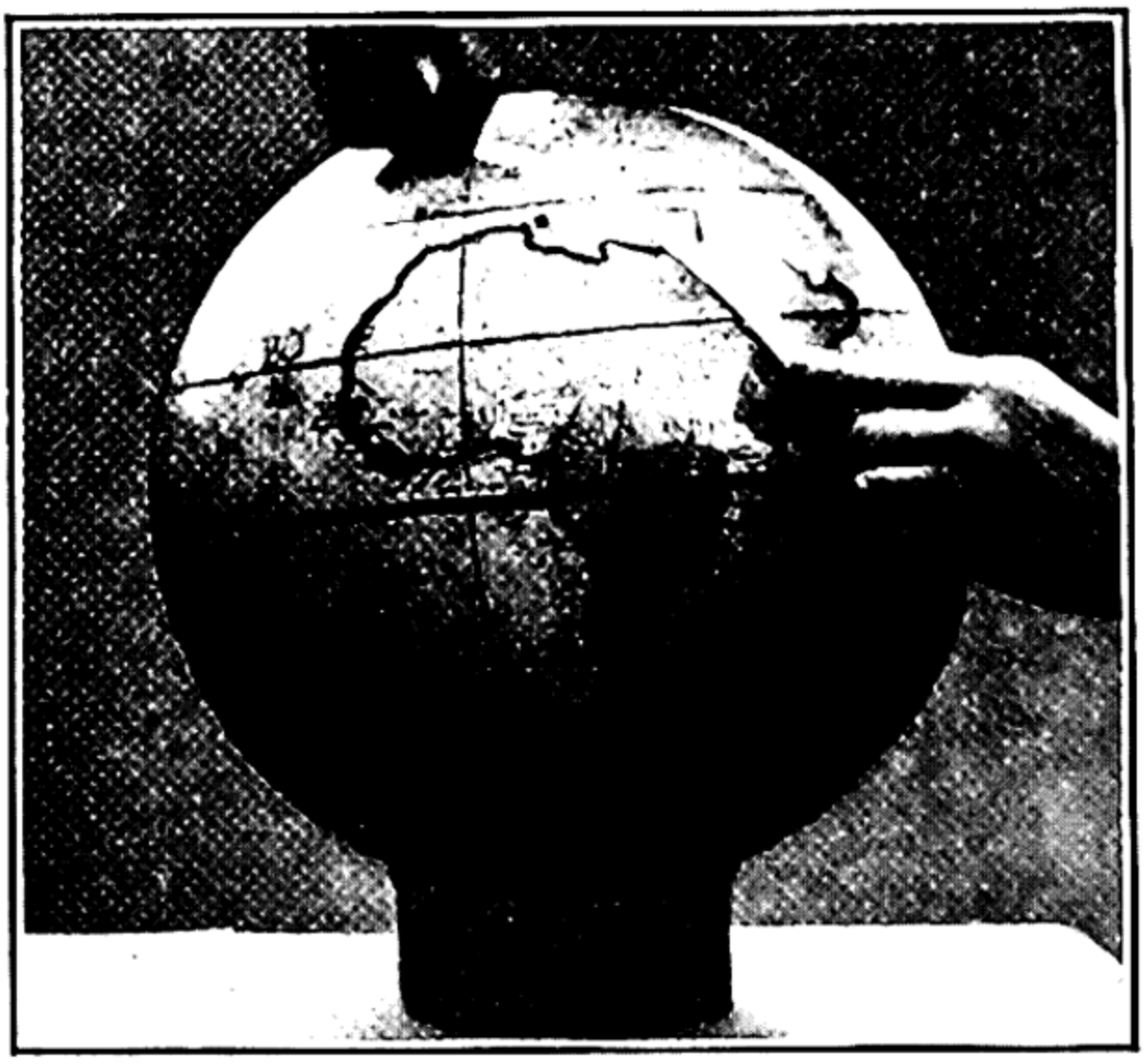
The lines in Fig. 88 are copied from the globe; the dot "a" lies where parallel 11½° S. crosses meridian 26° E. This is the position of the overhead sun.

C. 3. (*a*) Copy Fig. 88, mark the position of "a," and put in the positions in the following exercises:

Find where the sun is overhead on (*b*) March 21st, at 11 a.m. G.M.T., (*c*) October 28th, at 4.40 p.m., (*d*) June 21st, at 9 a.m. (Summer Time), (*e*) 10 a.m. April 24th (Summer Time).

LONDON AND ADEN

Some years ago a class of boys in a London school calculated that on the next day (April 24th), at 10 a.m. Summer Time, the sun would be overhead at Aden. The distance between London and Aden was measured on the globe and found to be 53°. When the time arrived, they measured the zenith distance of the sun, and that too came to 53°.



(*Photo by S. Wyles.*

FIG. 89.—FROM LONDON TO ADEN IS 53°.

Group Ex. Carry out a similar exercise for your own town.

THE MAP IN THE FRONT COVER

As it is not possible for all the members of a class to use the globe at the same time, the map in the front cover has been specially constructed for such exercises. Measure the

distance on it from London to Aden yourself to test whether it actually is 53°.

If we face towards the sun when it is overhead at Aden, across which lands are we looking ? The answer can be judged from the picture of the globe on page 44, or got more exactly from the map. Lay the edge of a piece of paper across from London to Aden and notice that it goes through Italy and over the Mediterranean.

A. 3. Make a full list from the map of the countries and seas between London and Aden.

A. 4. What lands and seas do I look across at the sun when it is overhead in (*a*) Ecuador, (*b*) the northern end of Madagascar, (*c*) Ceylon, (*d*) the S.W. corner of Nigeria.

D. 2. Calculate where the sun will be overhead in half-an-hour's time (or whatever time is convenient). Measure the distance in degrees on the map in the front cover or on the globe. Check your result with the quadrant.

What lands and seas will you be looking across then when you look towards the sun ?

D. 3. On what date and at what hour G.M.T. will the sun be overhead in (*a*) Quito, (*b*) Colombo, (*c*) north point of Madagascar, (*d*) south-west corner of Nigeria ?

THE SUNDIAL

In the sundial the angle that the gnomon (i.e. the rod that casts the shadow) makes with the ground is the same as its angle of latitude. In Nottingham, for example, in latitude 53° N., the gnomon makes an angle of 53° with the ground.

The dial can be placed at any angle so long as the sun can shine on it, but the simplest position is when it is at right angles to the gnomon. The hour lines are then easy to draw, the dial being like a clock face divided into 24 equal hour spaces.

Twelve o'clock noon is marked by the sundial when the sun is due south, and the times when this occurs is given on page 190 for various dates.

A SUNDIAL IN CARDBOARD

Make a rough drawing of Fig. 90, and on it mark the measurements for your own latitude.

AB is one inch long, or any length which is easily divided by ten

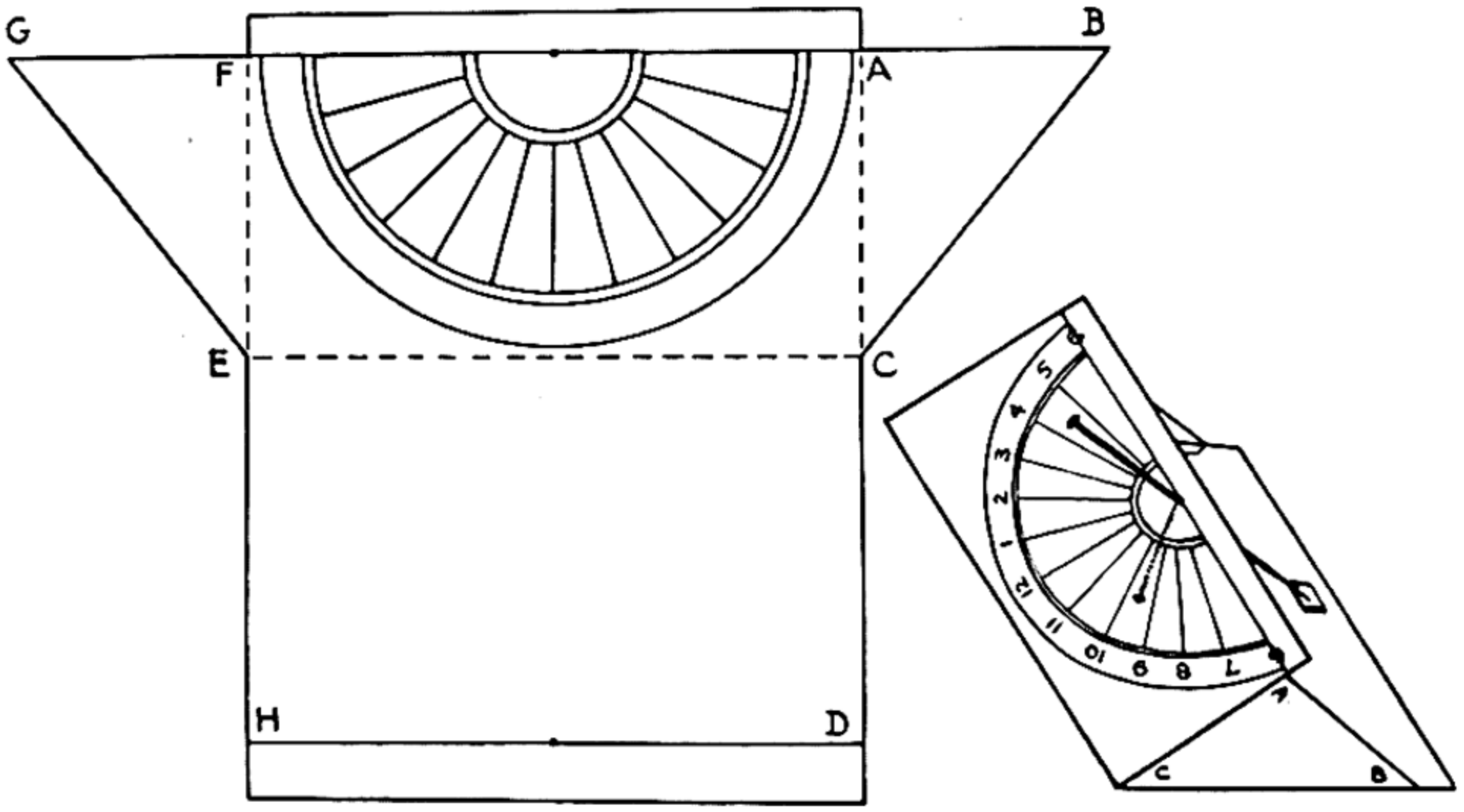


FIG. 90.—CONSTRUCTION OF SUNDIAL.

with a ruler. AC at right angles to AB is drawn of such a length as to make the angle at B equal to your latitude :

Latitude 50° .	.	1·19	
51½°	.	1·26	
53° .	.	1·33	
Latitude 54°	.	1·38	
55°	.	1·43	
56°	.	1·48	

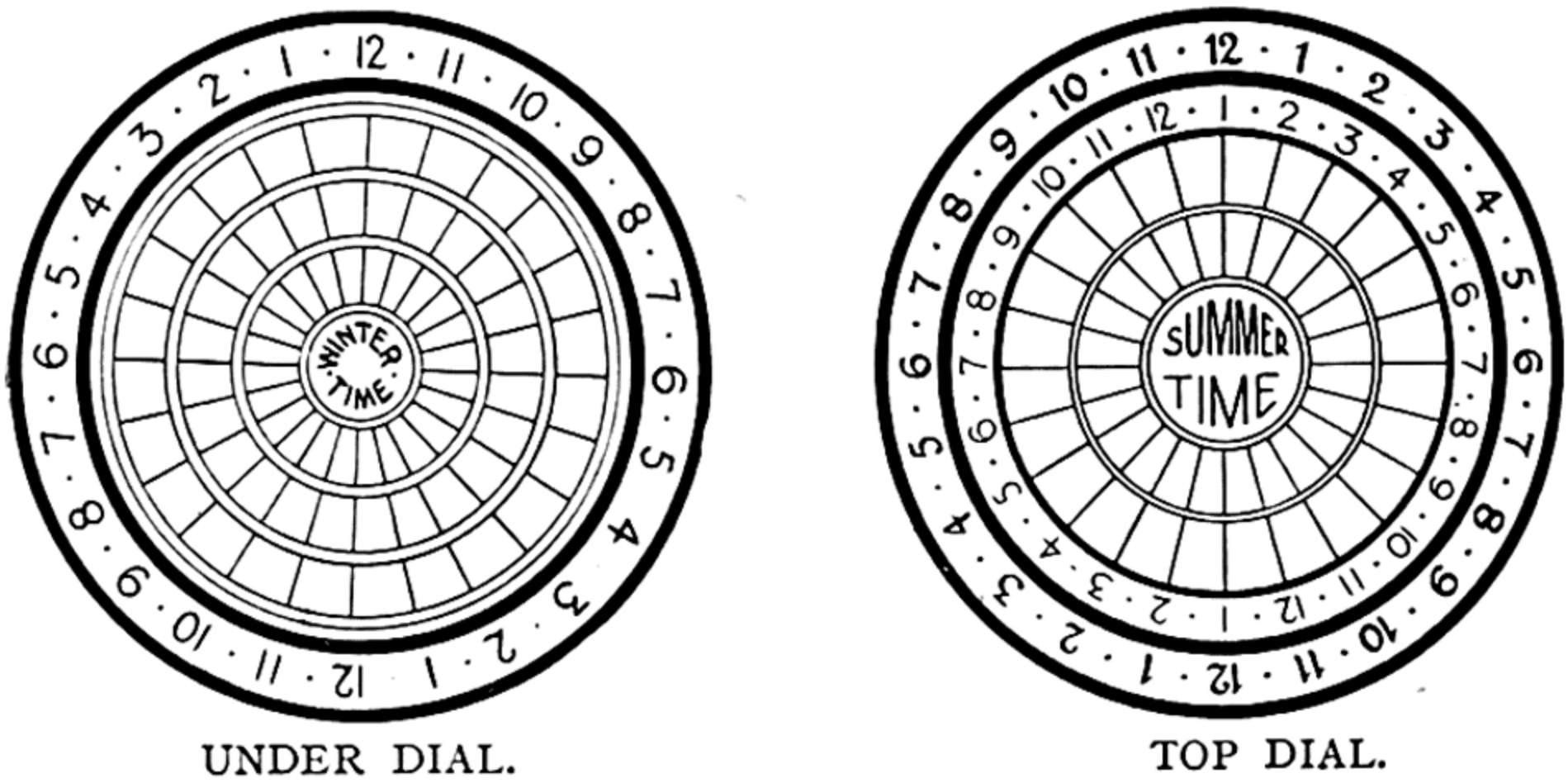
CD is the same length as CB. CE is double CA. The black dots are in the middle of the lines they lie on, and are to fix the position of the gnomon.

Draw a semicircle as shown,[1] and divide it into 12 hour sections, 6 a.m. to 6 p.m., numbering to the right. Prick through the hour marks to the back of the card and number them to the left, in order that 9 o'clock, for instance, shall be in the same position on both sides. Add the extra strips at the top and bottom to hold the gnomon pin.

Cut out the figure. Score along FE, EC, and CA and bend the card along these lines. Fasten DC, CB together with a strip of gummed paper, also HE and EG.

[1] If desired, the drawing can be extended to take a complete circle.

Push a pin through the dot in the centre of the dial and let its point just touch the other dot. The sundial is now ready for use.



UNDER DIAL. TOP DIAL.

FIG. 91.

SETTING THE SUNDIAL

The sundial should be placed on a north-south line with the gnomon pointing northward. In this position the gnomon is pointing to the pole star and is parallel to the axis of the Earth. At the same time the dial is parallel to the plane of the Equator, so that during the summer half of the year the sun shines on the top of it, while during the winter it shines underneath.

THE SUN CALENDAR

As the noonday sun is high in summer and low in winter, it is possible to make a calendar on which the date is given by the length of the noon shadow.

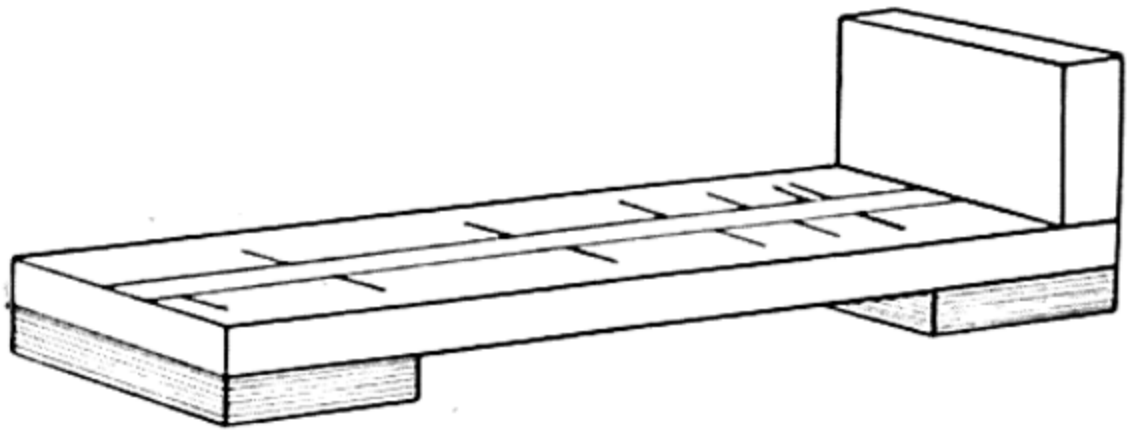


FIG. 92.—A SUN CALENDAR.

Take a flat piece of wood 4 inches long, 2 inches wide, and $\frac{1}{4}$ inch thick, and another piece 2 inches × 1 inch. Nail the smaller piece at right angles to the end of the larger so that it stands exactly an inch above it.

Along the larger piece draw two parallel lines a quarter of an inch apart, mark off the distances given below for the various months and write the names of the months. We now have a sun calendar

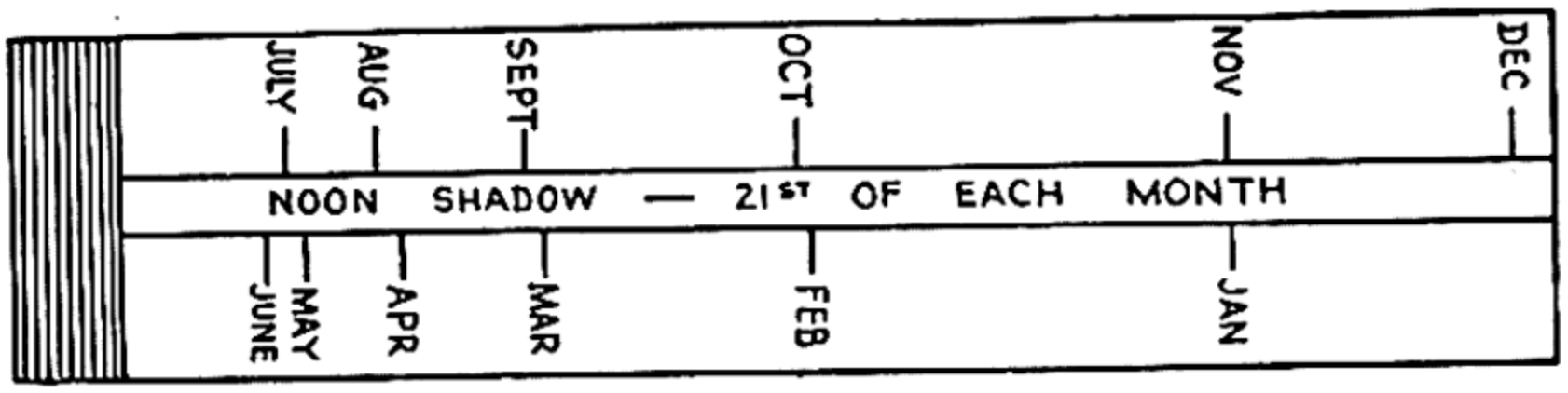


FIG. 93.—DIAL OF SUN CALENDAR.

with the lengths of the shadows indicated for the 21st of each month.

Place the calendar in the sunshine at noon with the upright end towards the sun. Its shadow will fall so as to give the date. The shadow shows up better if the calendar is drawn on white paper and stuck on to the board.

LENGTH OF SHADOW OF A 1-INCH GNOMON AT NOON

Date.	London.	Birmingham.	Newcastle.
January 21st . .	3·01	3·19	3·76
February 21st . .	1·91	2·00	2·04
March 21st . .	1·25	1·29	1·47
April 21st . . .	·82	·85	·93
May 21st . . .	·61	·63	·70
June 21st . . .	·53	·55	·61
July 21st . . .	·60	·62	·69
August 21st . .	·82	·85	·93
September 21st . .	1·22	1·26	1·39
October 21st . .	1·89	1·97	2·21
November 21st . .	2·97	3·15	3·70
December 21st . .	3·73	3·99	4·88

If the height of the board or gnomon that casts the shadow be doubled, then the lengths of the shadows must be doubled also.

THE TIDES

Twice every day at the seaside the tide rises and falls; to be more exact, each high tide comes on an average about 12 hours and 35 minutes after the preceding one. High tide is sometimes spoken of as "flood tide," and low tide as the "ebb."

SPRING TIDES AND NEAPS

The diagram shows the height of the highest tide each day during the same month at Hawaii out in the Pacific, Avonmouth near Bristol, and Dover. Notice how the height goes up and down in all three places. The highest high tides, occurring twice during the month, are the Springs ; between

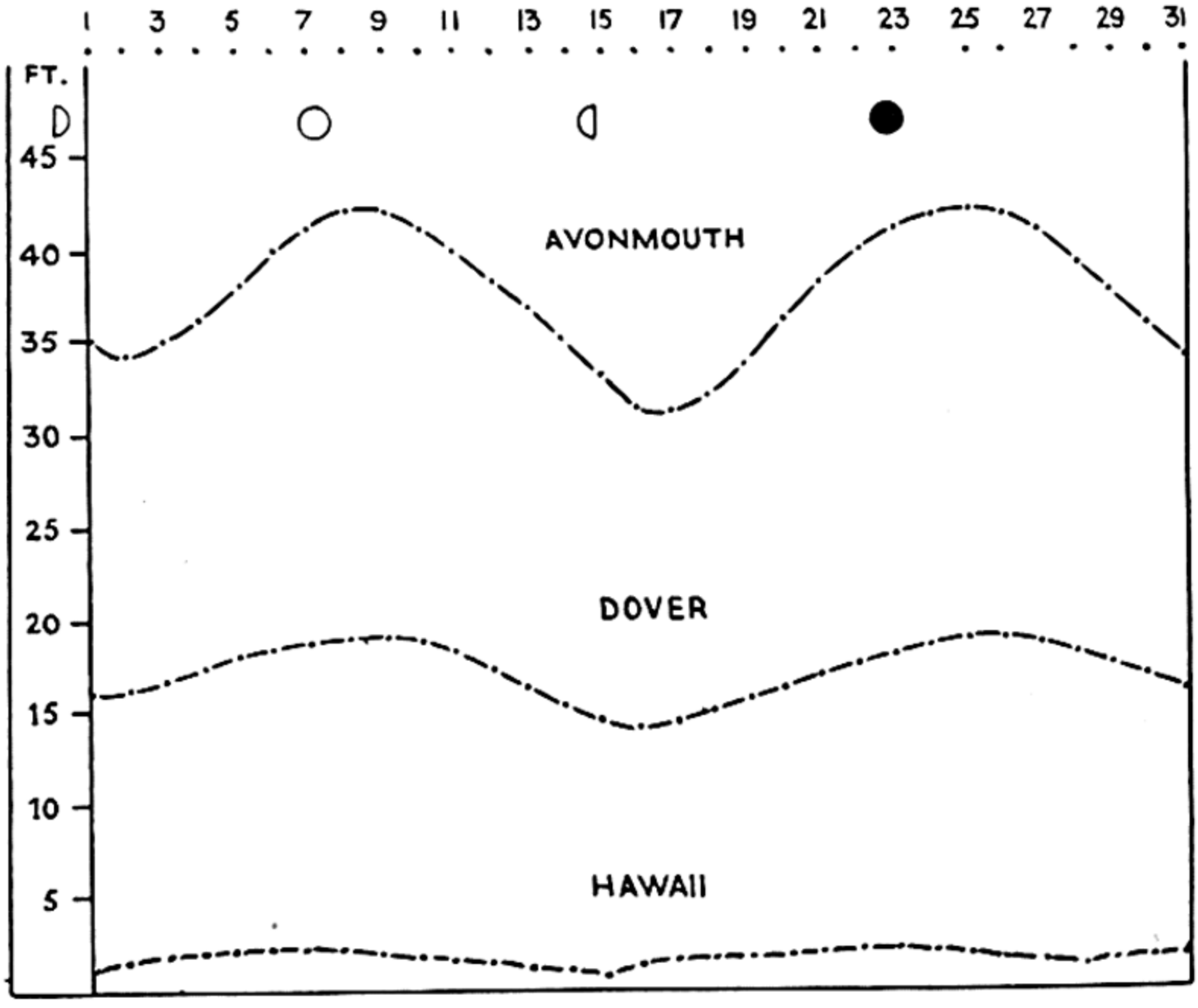


FIG. 94.—THE HEIGHT OF THE HIGHEST TIDE EACH DAY.

each pair of Spring Tides are the Neap Tides, which are not nearly so high. The phases of the moon are shown as well.[1]

A. 5. With which phases of the moon are the spring tides associated? How are the Earth, moon, and sun situated then with regard to one another: (*a*) in Britain, (*b*) in Hawaii?

THE HEIGHT OF THE TIDE

In mid-ocean the rise and fall of the tide (the " range " of tide) is only about two feet. In shallow seas like those round Britain the height is greatly increased, reaching the maximum at places situated at the head of a funnel-shaped estuary like

[1] The phases of the moon bear no relation to the calendar months and differ altogether in date from year to year.

the Bristol Channel. Here, as at Avonmouth, are the highest tides around our shores. Similarly, St. John, New Brunswick, being on the funnel-shaped Bay of Fundy, has higher tides than Halifax, Nova Scotia, which is on the open ocean, while at the head of the Bay of Fundy, in the Basin of Minas, are the highest tides in the world.

The tide that visits Honolulu takes about three days to travel round to us by way of the Indian Ocean and the Atlantic. That is why the Springs do not come to us in this country exactly with the full moon and new moon, as they do in the Pacific.

D. 4. Draw graphs like those in Fig. 94 for the following places (see table on page 196) :

(*a*) Lisbon and Brest. (*b*) Shanghai and Yokohama. (*c*) Halifax, N.S., and St. John, N.B. (*d*) Liverpool and Immingham. (*e*) Avonmouth, Dover, and Hawaii.

THE BRISTOL CHANNEL TIDE

In the map can be seen the difference between ordinary high and low tide in various parts of the Bristol Channel. At the mouth this range is 12 feet. Along a line joining Milford with St. Ives it is 14 feet. By the time we reach Barry the range is 24 feet, while at Avonmouth it is 32 feet.

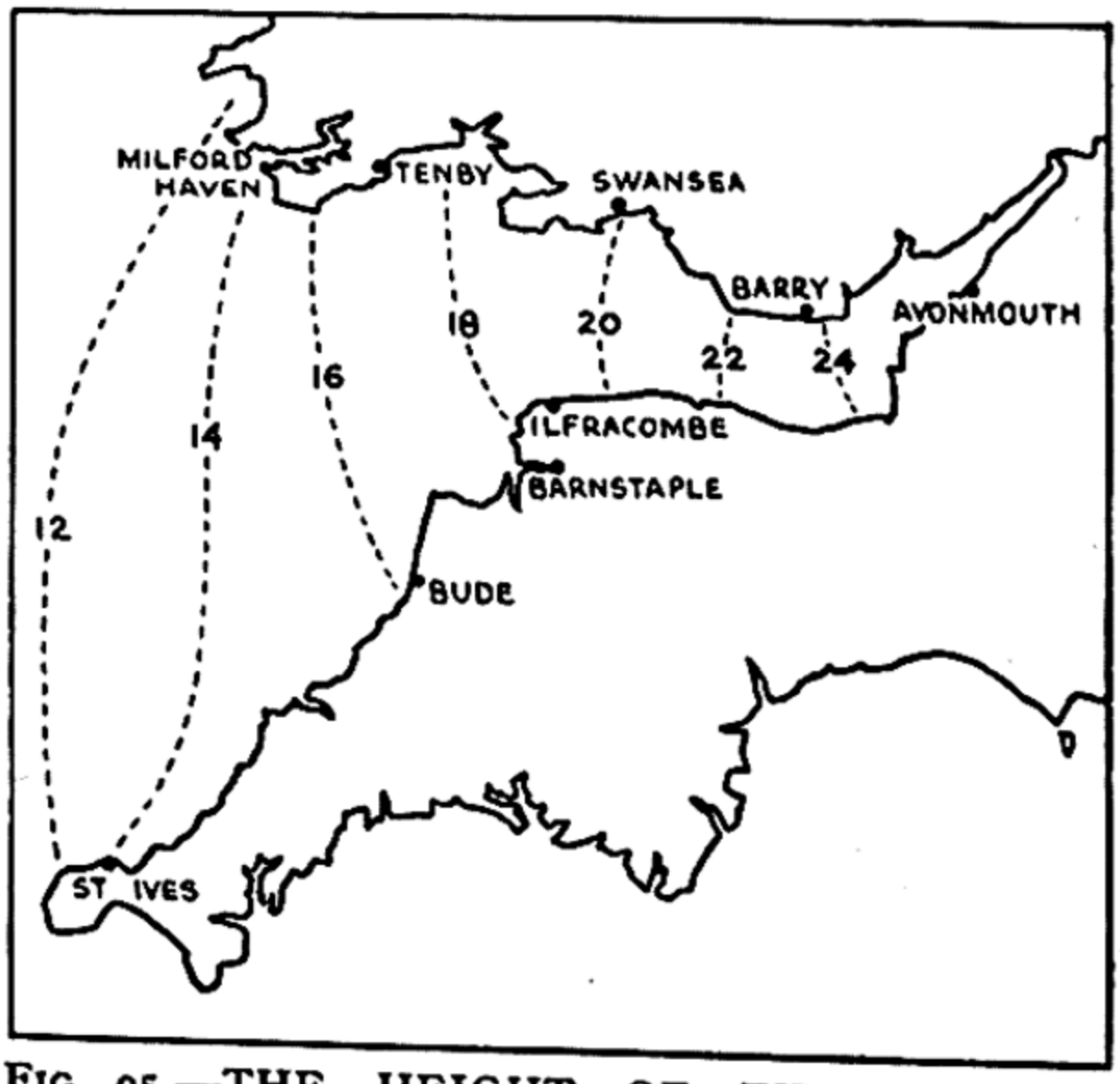


FIG. 95.—THE HEIGHT OF THE HIGHEST TIDES.

D. 5. Draw a graph to illustrate the change in the range of the tide in passing up the Bristol Channel. Let the low tides be represented by a horizontal line, on

which the distance from the entrance of the Channel is marked. The vertical scale can be 40 feet to an inch. Write " Low Tide " and " High Tide " on their proper lines.

QUESTIONS ON CHAPTER SIX

A. 1. If the full moon is seen in the east, in which direction is the sun ?
A. 2. At what phases of the moon does it appear close to the sun ?
A. 3. How can you watch the movement of the moon round the Earth ?
A. 4. What is meant by the revolution of the Earth ?
B. 1. What effect has the revolution on the climate of Britain ?
B. 2. How can the revolution of the Earth be watched ?
C. 1. What are the relative positions of the sun, moon, and Earth at the times of neap tides ?
C. 2. In placing a sundial in position, how would you decide on its correct setting ?
C. 3. Describe the construction of a sun calendar.
D. 1. Why is the summer half of the year longer in the northern hemisphere than in the southern ?
D. 2. By what method can you find or check the latitude of your house ?
D. 3. How can you calculate the position of the overhead sun " at this minute " ? How would you check your result experimentally ?

PART III

WEATHER AND CLIMATE

Chapter Seven

WEATHER AND CLIMATE

USUALLY when we speak of the weather we have in mind the wind, rain, and sunshine and temperature during a day or a week or even a month. If we meet a friend who has been on holiday for a week, we ask him what sort of weather he has had, but if we meet a man who has lived in India for twenty years we expect him to talk about the climate: "Weather for a week, climate for a number of years."

AVERAGES

In England July is generally the warmest month of the year and January the coldest. We think of July as the time of summer and sunny skies, yet we may need overcoats and umbrellas on holiday, while in January, when there might be snow and skating, we may feel uncomfortable on account of the mild, muggy weather and the drizzling rain.

Before making any statement, then, about the climate of a place we need to make many observations over a long series of years and to take "averages." The most useful averages for wind, rain, and temperature are the monthly and yearly averages, though in some of the following exercises we shall deal only with daily and weekly averages, as the figures for a month take so long to work out.

WEATHER OBSERVATIONS

Temperature

In Britain, temperature is measured by means of the Fahrenheit thermometer. This has a scale with the freezing-point at 32°, and boiling-point at 212°, so that there are 180 degrees between the freezing- and the boiling-points. In most countries the Centigrade scale is used. In this there are 100° between freezing and boiling, the freezing-point being 0°.

The Fahrenheit degree is $\frac{100}{180}$ or $\frac{5}{9}$ of the degree Centigrade.

A comparison between the two scales is to be found on page 197.

CLASSROOM TEMPERATURES

The temperature in a classroom was recorded every school hour for a week. The figures for Monday were :

9 a.m.	10 a.m.	11 a.m.	12	2 p.m.	3 p.m.	4 p.m.
54	56	60	62	58	63	61

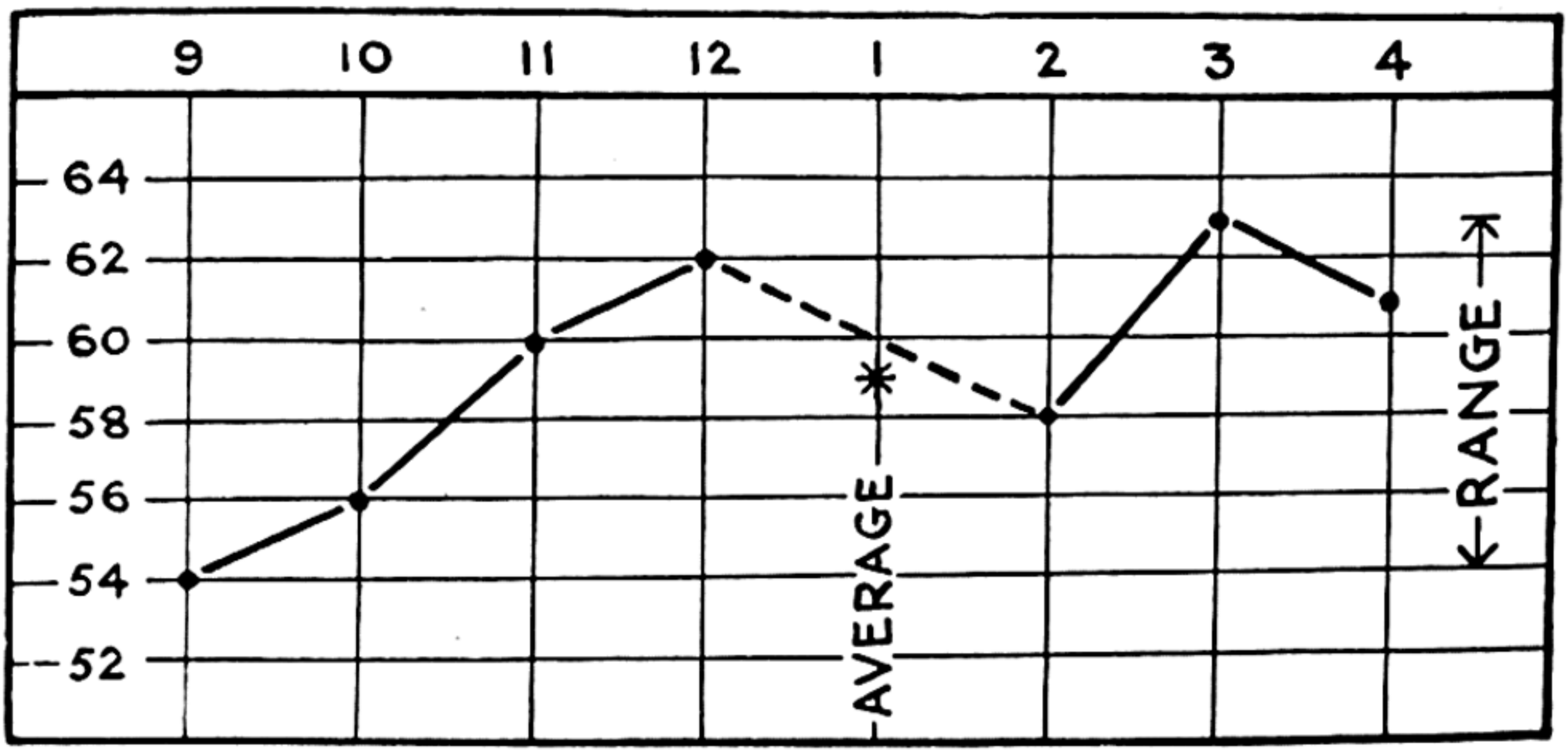


Fig. 96.—CLASSROOM TEMPERATURES.

A graph was then drawn (Fig. 96) which showed the up-and-down movement of the thermometer, the average for the day and the "range," that is the distance between the highest and lowest readings.

A. 1. Draw the graph with the average and the range. (Use ordinary exercise paper and let the hour lines be half an inch apart.)

The record was continued for a week and the following table made :

	a.m.				p.m.			Total.	Average.	Order.
	9	10	11	12	2	3	4			
Monday .	54	56	60	62	58	63	61	414	59·1	
Tuesday .	60	62	66	68	64	69	67			
Wednesday .	61	61	62	63	63	63	62			
Thursday .	58	60	64	66	62	67	65			
Friday .	59	61	65	67	68	67	63			

B. 1. Draw the graph for Tuesday (add the average and range).
B. 2. Find the average for each day in the week. Arrange the days in order from the warmest to the coolest.
B. 3. Find the average for the week by adding up the daily averages and dividing by 5.
C. 1. In the following table the average of the five 9 a.m. temperatures has been found. Copy the table and complete it.

	a.m.				p.m.		
	9	10	11	12	2	3	4
Total .	292						
Average .	58·4						

Draw the graph of the averages.

MAXIMUM AND MINIMUM TEMPERATURES

The highest temperature during the day or month is called the maximum temperature, the lowest the minimum temperature.

A. 2. What are the maximum and minimum temperatures for Monday?
What is the range between them ?
Find their average. How much does it differ from the average in the graph ?

TEMPERATURE OBSERVATIONS

To make a complete record of the temperature at any place we need to have the thermometer read every hour, night and day. As it is seldom possible to have this done so frequently, it is usual to employ a " maximum " and a " minimum."

The maximum thermometer is like the one with which the doctor takes his patient's temperature. The mercury in it will go " up," but will not come down until the instrument is shaken. If, therefore, a maximum thermometer is left for

a day it shows the highest temperature for that day; this generally occurs at the beginning of the afternoon.

In one type of minimum thermometer there is a thin metal rod that will only move down and therefore shows the lowest temperature for the day. This, as a rule, is just before dawn.

The best time for reading the two thermometers is at 9 a.m. The maximum reading, being that of the previous afternoon, is then plotted for the preceding day. The minimum reading is plotted for the day of observation.

For scientific purposes, the thermometers are placed in the open, four feet above the ground, in a " screen " which protects them from the rain and sun but allows air to move freely over them.

In school such placing is seldom possible, and we have to make the best of such arrangements as can be devised.

SOMETHING TO DO

Take the maximum and minimum temperatures daily for a month. Find the average for each day and then for each week. When the observations are finished find the average for the whole month.

In the accompanying table are the figures for Greenwich in

DAILY TEMPERATURES, GREENWICH (JANUARY 1930)

	Max.	Min.	Mean.		Max.	Min.	Mean.		Max.	Min.	Mean.
1	51	32	41·5	12	52	33	42·5	23	49	46	47·5
2	53	44	48·5	13	52	40	46·0	24	50	46	48·0
3	52	48	50·0	14	55	51	53·0	25	47	33	40·0
4	51	45	48·0	15	54	41	47·5	26	44	31	37·5
5	49	40	44·5	16	45	39	42·0	27	51	42	46·5
6	45	36	40·5	17	49	40	44·5	28	43	40	41·5
7	49	42	45·5	18	54	41	47·5	29	48	35	41·5
8	45	36	40·5	19	59	46	52·5	30	46	31	38·5
9	47	32	39·5	20	48	34	41·0	31	42	33	37·5
10	47	38	42·5	21	46	28	37·0				
11	47	33	40·0	22	49	37	43·0				1356·0

1356 ÷ 31 = 43·7, the Mean for the Month.

January 1930. The average for each day has been found and the average for the month.

C. 2. Draw a graph of the maximum and minimum temperatures from the table for January 1–16 inclusive. Find the average for each day without arithmetic by putting a dot half-way between the two temperatures. (Use ordinary exercise paper and let each day be ¼ inch wide.)

AVERAGE MONTHLY TEMPERATURES

The January temperature for Greenwich given below is 38·6° F. This was found by taking the average of all the

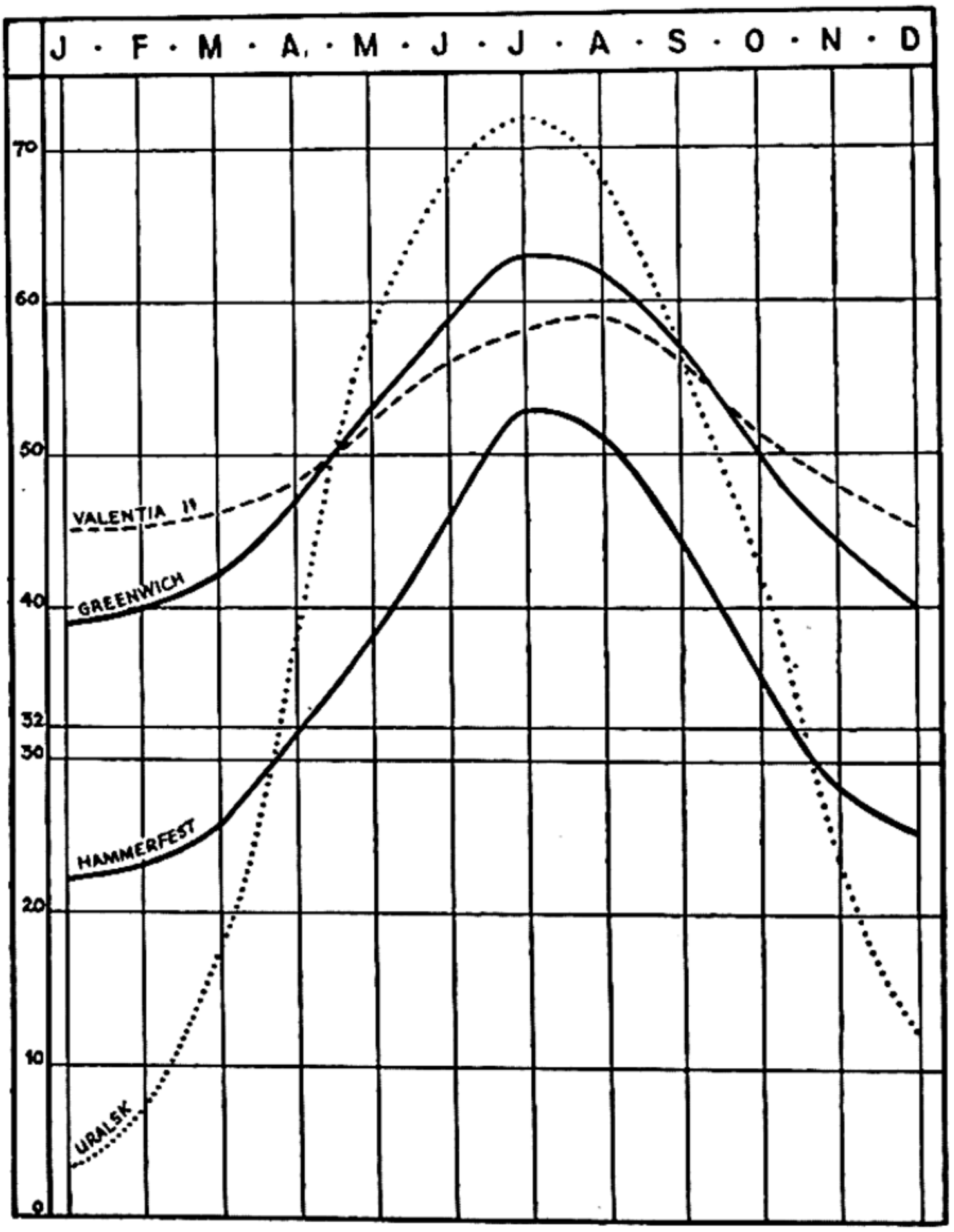


FIG. 97.—AVERAGE MONTHLY TEMPERATURES.

January figures between 1841 and 1905. The average monthly temperatures for the rest of the year were found in

the same way. It is not possible to go back so many years with all stations, and sometimes we have to be satisfied with an average of four or five years.

AVERAGE MONTHLY TEMPERATURES

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Greenwich . .	39	40	42	47	53	59	63	62	57	50	44	40
Hammerfest . .	22	23	25	32	38	46	53	51	44	35	28	25

B. 4. Draw the temperature graph for Greenwich.
B. 5. Draw the temperature graph for Hammerfest on the same sheet.

WORLD TEMPERATURES

(Temperature figures will be found on page 186).

Distance from the Ocean

C. 3. Arrange the following in order according to their distance from the Atlantic, and against each write (*a*) the January temperature, (*b*) the July temperature, (*c*) their average, (*d*) their difference or range.

What relationships do you notice ?

Berlin, Breslau, Greenwich, Orenburg, Utrecht Valentia Is., Warsaw.

In the following exercises use different kinds of lines for the curves (see Fig. 97).

Oceanic and Continental Stations

C. 4. On the same sheet graph the temperatures of Manila, Khartoum, Winnipeg, Vancouver. What do the graphs illustrate ?

AVERAGE MONTHLY TEMPERATURES (° F.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Manila. . .	77	78	80	83	83	82	81	81	80	80	78	77
Khartoum . .	72	75	81	88	92	93	90	88	89	89	82	75
Winnipeg . .	3	1	15	39	51	62	66	63	54	42	25	7
Vancouver . .	36	38	42	47	54	59	63	62	56	49	43	38

The Western Shores of Europe

C. 5. Lisbon, Brest, Valentia Is., Hammerfest (see B. 5).
Draw these on the same graph, add the curve for Orenburg. What do the effects of latitude and nearness to the sea appear to be?

AVERAGE MONTHLY TEMPERATURES (° F.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Lisbon . . .	50	52	54	58	62	67	70	71	68	63	56	50
Brest . . .	46	46	47	50	55	59	63	63	61	56	50	46
Valentia Island .	45	45	45	48	52	56	59	59	56	52	47	45
Hammerfest. .	22	23	25	32	38	46	53	51	44	35	28	25
Orenburg . .	4	8	18	25	59	67	72	67	55	40	24	12

Equatorial Stations

C. 6. Draw the temperature graphs of (*a*) Para, Quito, and Singapore, (*b*) Colombo, Libreville, and Nairobi. Find these places in your atlas and comment on their likenesses and differences of temperature.

AVERAGE MONTHLY TEMPERATURES (° F.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Para . . .	78	77	78	78	78	79	78	78	78	79	80	79
Quito . . .	55	55	55	55	55	55	55	55	55	55	55	55
Nairobi . .	64	65	65	64	63	62	59	59	62	65	64	62
Colombo . .	79	80	82	83	83	82	81	81	81	80	80	79
Batavia . .	78	78	79	80	80	79	79	79	80	80	79	79
Singapore . .	79	81	81	82	82	81	81	81	81	81	81	79

TEMPERATURE AND ALTITUDE

Temperatures become lower as we ascend, so that Fort William, for instance, at the foot of Ben Nevis in Scotland, is always warmer than the summit of the mountain. In Equatorial regions, too, there are mountains whose summits are always covered with snow.

C. 7. Draw graphs for the following groups of places:
(*a*) Fort William and Ben Nevis.
(*b*) Lisbon and Madrid.
(*c*) Cheyenne and Denver, St. Louis.
In each case how far must we ascend on the average for the temperature to drop 1° F.?

AVERAGE MONTHLY TEMPERATURES (° F.)

	Alt. Feet.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Fort William	12	39	39	41	45	50	56	57	57	54	48	43	40
Ben Nevis	4,407	24	24	24	28	33	40	41	41	38	31	29	25
Lisbon .	331	50	52	54	58	62	67	70	71	68	63	56	50
Madrid .	2,150	40	43	47	53	61	69	77	76	66	56	47	40
Cheyenne .	6,058	26	26	33	41	51	61	67	66	57	45	35	28
Denver .	5,280	30	32	39	47	57	67	72	71	62	51	39	32
St. Louis .	568	30	35	43	56	66	75	79	77	70	57	44	36

THE WIND

When we take the temperature with a thermometer or measure the amount of rain in the gauge, we need to record only a single number ; but when we consider the wind we find that it is necessary to record several things about it: from which direction is it blowing, is it steady or does it come in gusts, is it warm or cold, wet or dry ?

OBSERVATIONS TO MAKE

Make a record of the wind for a week, using the following table as a guide. The observation should be made at the same time each day.

	Direction.	Force and Character.	
Monday . .	N.N.E.	Strong, gusty.	Dry and cold.
Tuesday . .	S.W.	Moderate, steady.	Warm and rainy.

Instead of one observation a day it is better to make two or even three. The same number, however, must be made each day and at the same times.

The direction of the wind may be recorded on a wind-rose.

Copy Fig. 29, making the arms 3 inches long and dividing them up into sections of a $\frac{1}{4}$ inch. The record may be made either by thickening one of the sections or by writing the date against it.

At the end of the period the points may be joined up and the figure obtained shaded.

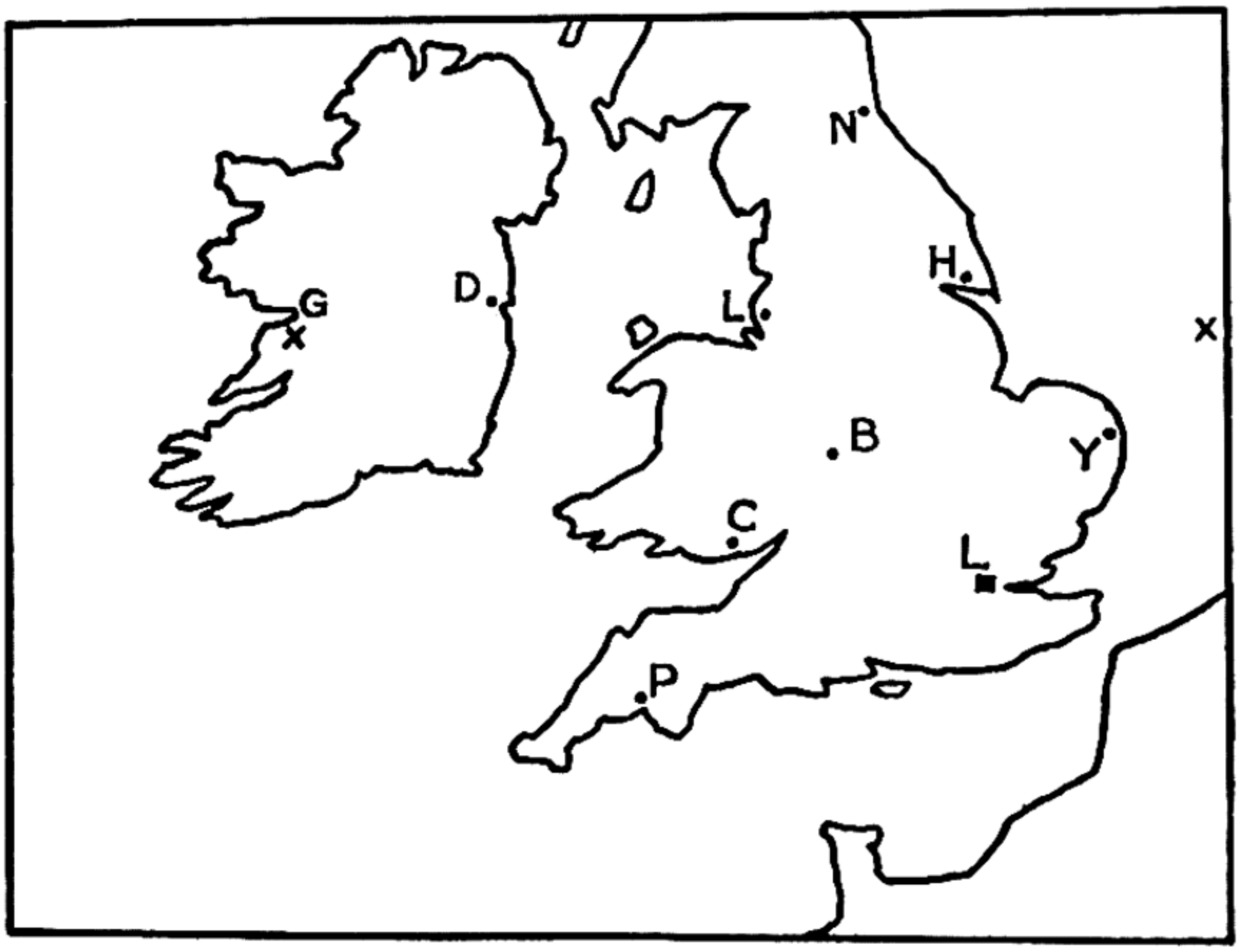


FIG. 98.

WINDS IN THE BRITISH ISLES

The map and the diagram will help us to understand first some of the changes of wind that take place in our islands, and secondly how the direction of the wind for the next day can sometimes be forecast. Wind-swirls like the one in the diagram are continually crossing the Atlantic to the shores of Europe. The centres of most of them pass to the north of us, but we will consider here a case where the centre travelled due east across the middle of the country. On Wednesday the centre was near Galway, on Thursday over Anglesey, and on Friday off the Humber.

AN EXPERIMENT

C. 8. Mark out the winds on a piece of tracing-paper. Place the X which indicates the centre of the swirl over the X on the west coast of Ireland. Note the directions of the winds in Dublin, Cardiff, Plymouth, Birmingham, Newcastle, London, and Yarmouth. Next place the centre on the Island of Anglesey and note again the directions of the winds in Dublin, Cardiff,

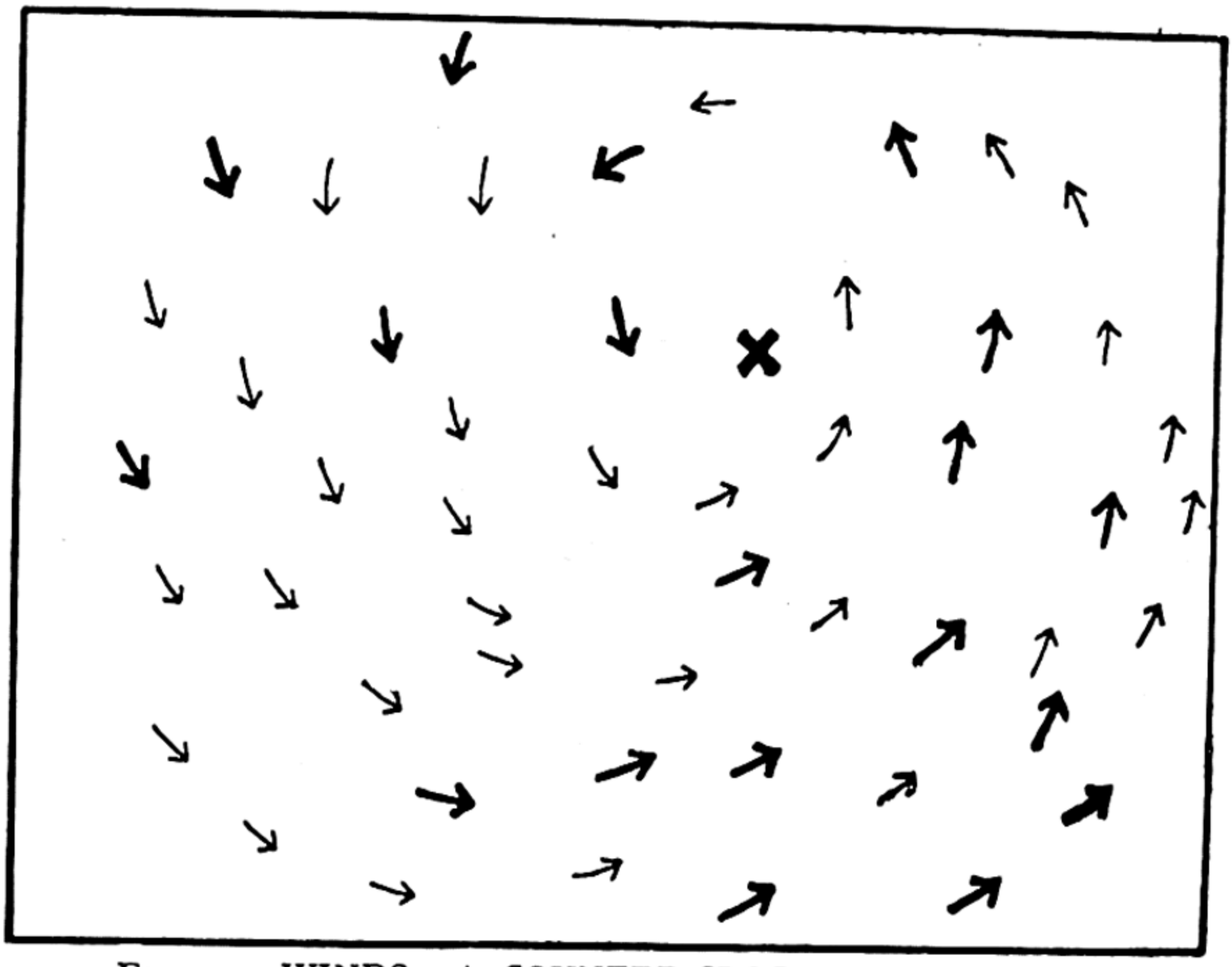


FIG. 99.—WINDS. A COUNTER-CLOCKWISE SWIRL.

Plymouth, etc. Finally, place the centre on the X on the eastern edge of the map.

Record your answers in this manner :

Place.	Wednesday.	Thursday.	Friday.
Plymouth .	S.W.		

C. 9. On a map of Europe the centre of the swirl of winds is over the centre of Iceland. Move the centre dot on the tracing-paper across the map in that latitude. What is the general direction of the winds all over England and Wales ?

VEERING AND BACKING

When the change in its direction is " clockwise " from N. to N.E. the wind is said to " veer."

If the change is against the clock, the wind " backs." It backs, for instance, in changing from S.W. to S.

RAINFALL

There are two ways of comparing the rainfall of a number of places. The first is to measure the amount that falls during each month, and the second to count the number of rainy days.

The Rain-gauge

The amount of rainfall is measured by means of a rain-gauge. This is a cylinder or jar which is placed out in the open right away from all shelter of trees or buildings. Its top is an inch above the ground and quite level, and the edge round the top is made sharp so that there can be no flat space on which splashing may occur. There is a funnel in the mouth of the rain-gauge which allows the water to run through into a bottle, but prevents evaporation. The top of the funnel should be six inches below the top of the cylinder.

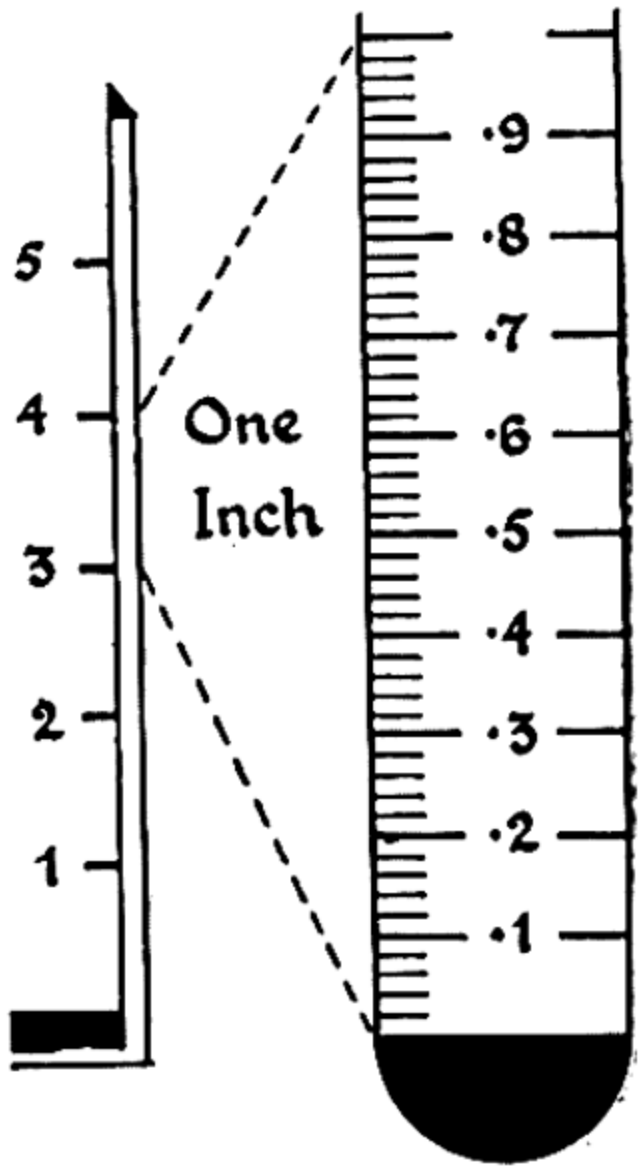


Fig. 100. — MAGNIFYING AN INCH OF RAINFALL.

The amount of rainfall is recorded in inches or millimetres by a scale on the side of the bottle, but since in this country there is generally too small a quantity for it to be read at all accurately by this scale, a measuring glass is supplied. This is much smaller in diameter than the cylinder, and magnifies the height of the water.

In the diagram an inch of water in the rain-gauge becomes six inches in the measuring-glass.

RAINFALL GRAPHS

The depth of rain that has fallen is recorded month by month at innumerable stations throughout the world, and the averages found. By making graphs of these averages we can judge the types of rainfall that are experienced in various regions.

On exercise paper ruled out in quarter-inch columns mark off thirteen spaces horizontally. Write " in " for inches in

the first one and put the initial letter of a month in each of the others : J, F, M, A, etc.

Number the lines for inches as shown in Fig. 101, taking care that there is room for the maximum reading (e.g. if the highest month is 3·7 inches, make the graph 4 inches). Add the name of the station.

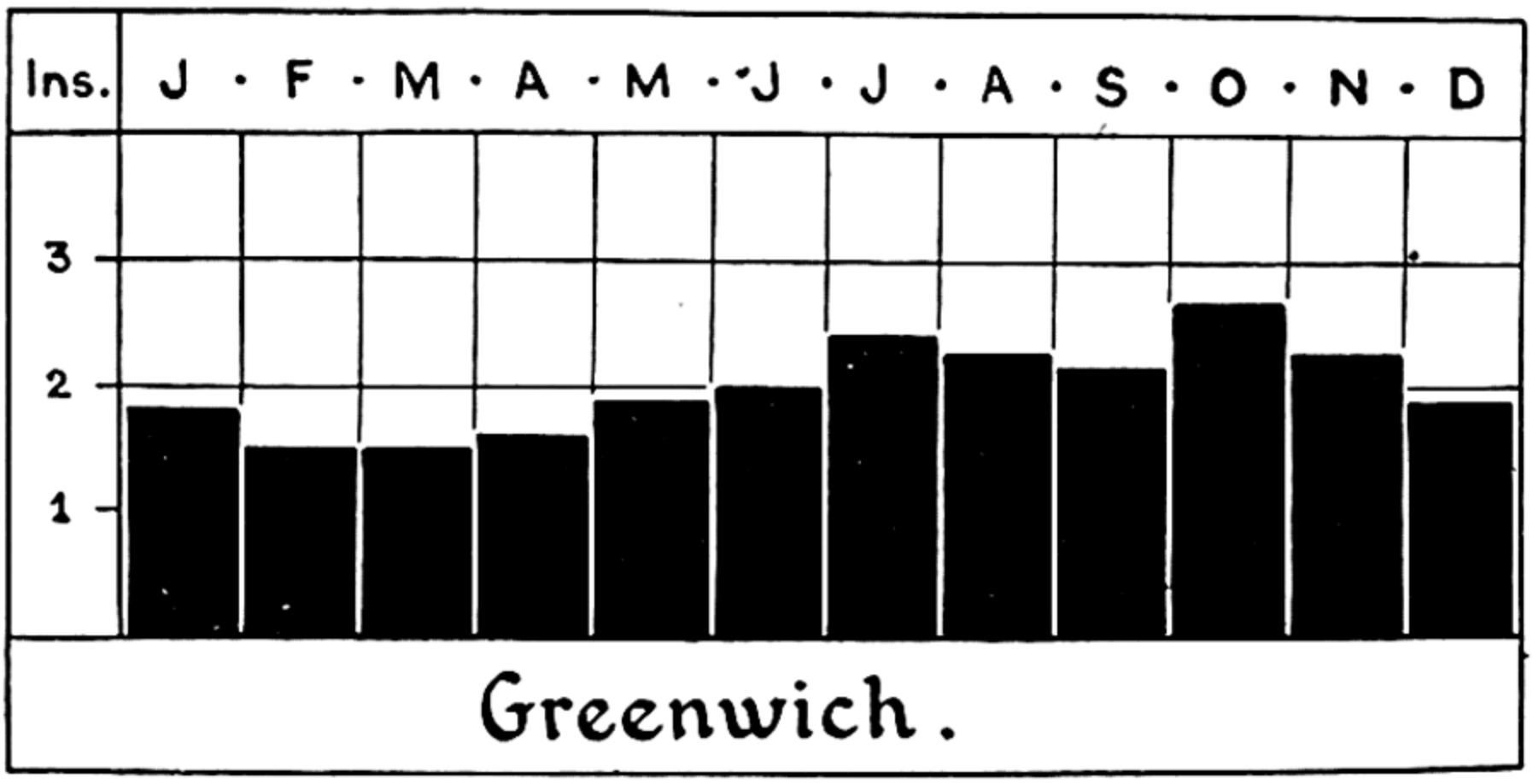


FIG. 101.

B. 6. Here are the rainfall figures for Greenwich. Draw the graph and compare your result with Fig. 101.

J	F	M	A	M	J	J	A	S	O	N	D
1·9	1·5	1·6	1·6	1·9	2·0	2·4	2·3	2·1	2·7	2·2	2·0

B. 7. Draw graphs for the following pairs of stations and explain to what the difference in each pair is due :

(*a*) Southport and Scarborough. (*b*) Holyhead and Yarmouth. (*c*) Oban and Aberdeen. (*d*) Fort William and Ben Nevis.

AVERAGE MONTHLY RAINFALL (INCHES)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Southport . .	2·6	2·1	2·2	1·9	2·1	2·2	2·9	3·5	2·8	3·5	3·1	3·2
Scarborough. .	2·0	1·7	1·8	1·6	1·9	1·8	2·4	2·8	1·8	3·1	2·5	2·4
Holyhead . .	2·9	2·4	2·6	2·1	2·0	2·2	2·6	3·2	2·7	4·0	4·1	4·2
Yarmouth . .	1·7	1·5	1·8	1·5	1·7	1·8	2·3	2·5	2·0	2·9	2·4	2·4
Aberdeen . .	2·1	2·1	2·4	2·0	2·3	1·9	2·9	2·9	2·5	3·0	3·2	3·2
Fort William .	9·6	7·4	6·6	4·4	3·9	3·5	4·9	6·1	6·3	7·0	8·1	10·1
Ben Nevis . .	18·6	13·8	15·5	8·6	8·0	7·7	11·0	13·6	16·0	15·7	15·6	19·4

B. 8. Draw rainfall graphs of the following pairs of towns and endeavour with the aid of an atlas to account for the difference in each case. (Both graphs can be done in the same framework.)
(*a*) Valentia Is. and Greenwich. (*b*) Bergen and Stockholm. (*c*) Fort William and Aberdeen. (*d*) Hokitika and Christchurch, N.Z. (*e*) Utrecht and Orenburg.

AVERAGE MONTHLY RAINFALL (INCHES)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Valentia Island .	5·9	5·1	4·4	3·8	3·2	3·5	3·9	4·8	4·5	5·9	5·4	6·5
Greenwich . .	1·8	1·5	1·5	1·6	1·9	2·0	2·4	2·3	2·1	2·7	2·3	1·9
Bergen . .	5·9	6·5	3·5	3·4	3·4	4·3	5·1	7·2	8·1	8·7	6·7	8·0
Stockholm . .	0·8	0·7	0·8	0·9	1·4	1·7	2·3	2·4	1·8	2·0	1·4	1·1
Fort William .	9·6	7·4	6·6	4·4	3·9	3·5	4·9	6·1	6·3	7·0	8·1	10·1
Aberdeen . .	2·1	2·1	2·4	2·0	2·3	1·9	2·9	2·9	2·5	3·0	3·2	3·2
Hokitika, N.Z. .	10·0	7·4	9·7	9·2	9·8	9·8	9·1	9·2	9·3	11·7	10·6	10·4
Christchurch, N.Z.	2·2	1·7	2·4	2·0	2·3	2·4	2·9	2·0	2·0	1·6	2·0	2·1
Utrecht . .	2·1	1·7	2·0	1·7	2·0	2·3	3·0	3·3	2·6	2·9	2·4	2·7
Orenburg . .	1·2	0·7	0·9	0·8	1·3	1·6	1·4	1·3	1·0	1·2	1·4	1·4

For the effect of altitude on rainfall see page 198.

COMBINED RAINFALL AND TEMPERATURE GRAPHS

Both the rainfall and the temperature graphs can be drawn in the same frame if an extra column is added for the rainfall scale. When the two dotted lines marking the range of temperature in your own town are added to the graphs of Bombay, etc., they afford a method of judging the conditions at the other places.

C. 10. Draw combined rainfall and temperature graphs for the following places and in each case look for some relationship between the two graphs. Add the dotted lines showing the range of

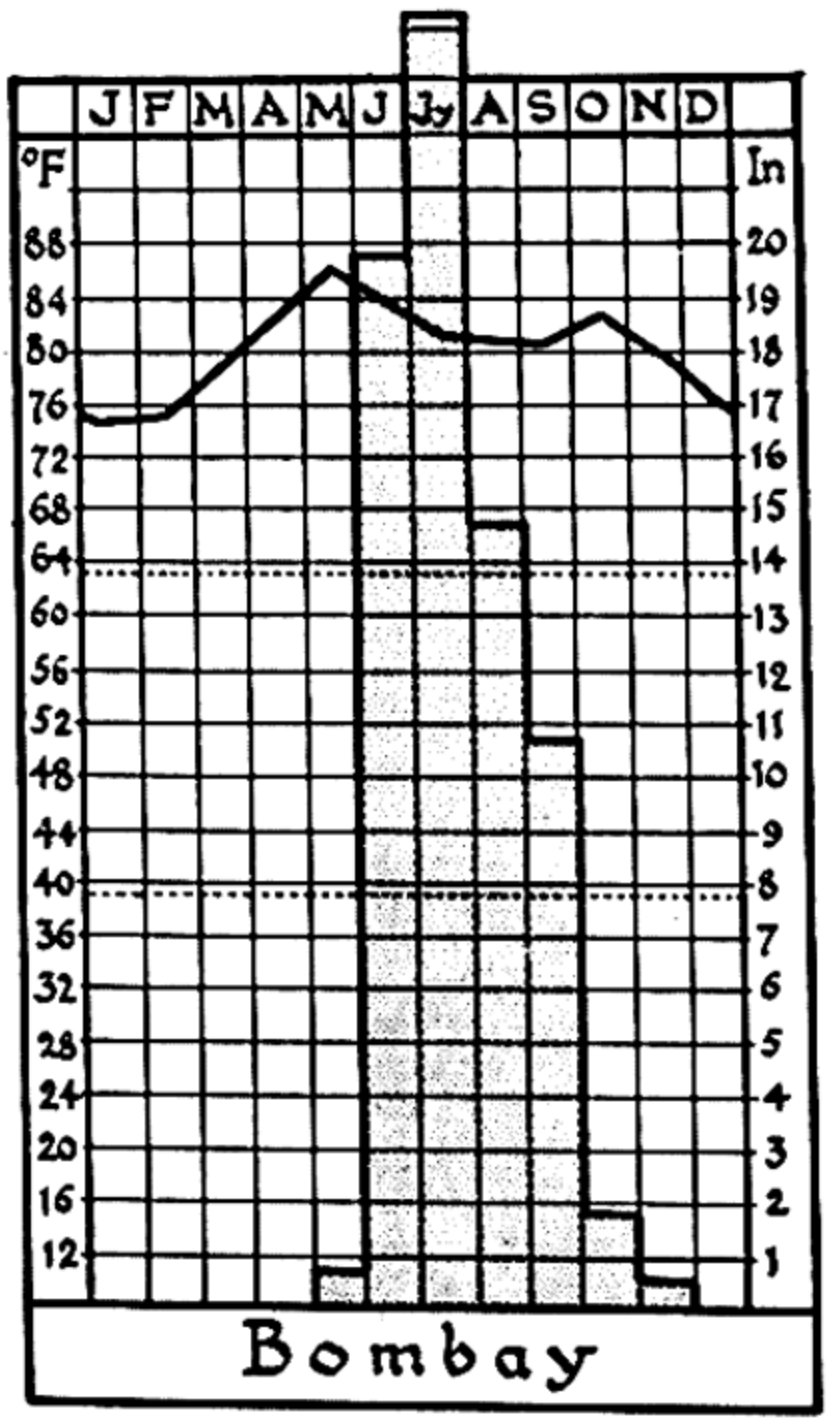


FIG. 102.—AVERAGE RAINFALL AND TEMPERATURE.

temperature at Greenwich, or your own town. The figures will be found on pages 186 and 187.

(*a*) Bombay, (*b*) Khartoum, (*c*) Colombo, (*d*) Alexandria, (*e*) Winnipeg.

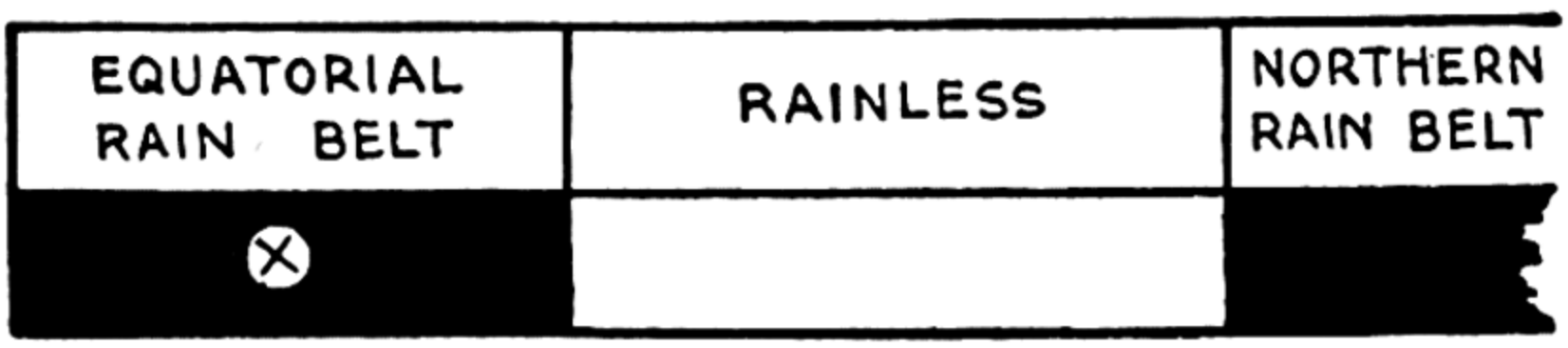


FIG. 103.

THE SWING OF THE RAIN BELTS

The Sahara desert lies between two belts of rainfall, one to the north, which extends over Britain and Europe, and one to the south. In the northern half of Africa it is possible to observe the migration of these three belts (rain, desert, rain) northward with the sun in our summer and southward with the sun in our winter. The migrations give rise to four rainfall regions: (1) Equatorial, (2) Sudan, (3) Desert, (4) Mediterranean.

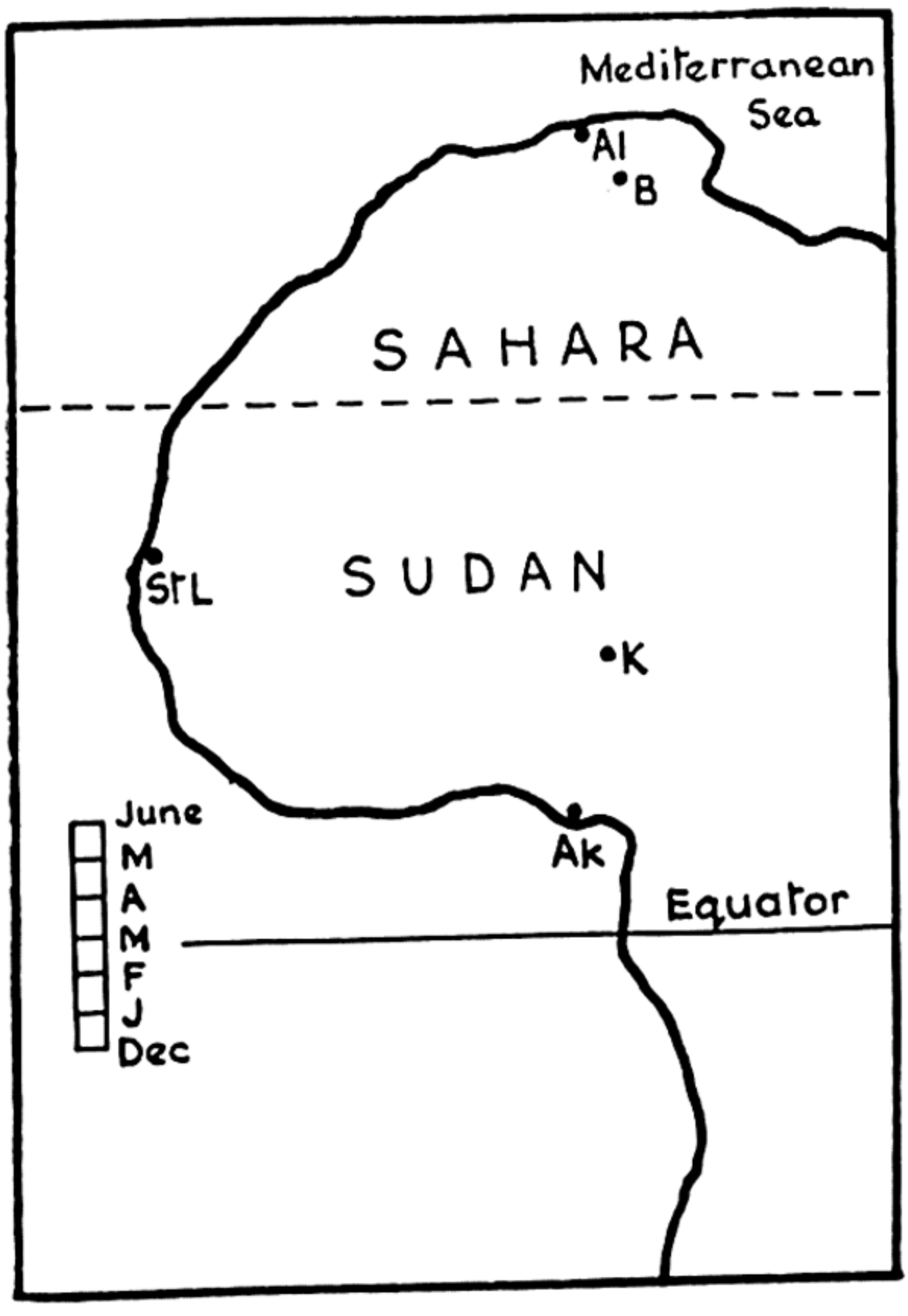


FIG. 104.

Fig. 103 and the map in Fig. 104 will assist us in understanding how these four types are brought about, but it must be kept firmly in mind that we are dealing only with a diagram

and that there are no straight-line boundaries between the belts themselves in Africa.

An Experiment

C. 11. Make a copy of Fig. 103 on the edge of a sheet of paper.
(*a*) Lay it on the map with the X against the June mark. The Equatorial rain belt then extends over the Sudan, while the Sahara and the Mediterranean are rainless.
(*b*) Move it until the X is against the December line. The Sahara and the Sudan are now rainless, while the northern rain belt is over the Mediterranean part of Africa.

C. 12. Make a table showing which are the seasons of rainfall in the following :
(*a*) The Equatorial lands, (*b*) the Sudan, (*c*) the Sahara, (*d*) the Mediterranean lands.

C. 13. Which should you judge from the diagram has the longer rainy season, Algiers or Biskra, Kano or Akassa ? Draw the rainfall graphs of the four towns, and on each write its rainfall season.

C. 14. Draw the rainfall graphs of (*a*) Alexandria, Helwan, and Khartoum, (*b*) Perth (W.A.), Cape Town, and Bulawayo. Against each write the season at which the greatest rainfall occurs.

AVERAGE MONTHLY RAINFALL (INCHES)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.
Akassa . .	2·5	4·4	6·2	9·4	15·4	28·5	22·6	12·1	24·6	19·6	9·6	4·8
Algiers .	3·9	2·4	3·2	2·1	1·8	0·7	0·2	0·2	1·1	3·1	3·4	3·7
Biskra .	0·7	0·7	0·7	0·8	0·7	0·3	0·1	0·1	0·8	0·6	0·4	0·7
Kano .	0·0	0·0	0·1	0·5	3·2	4·8	6·9	11·3	5·0	0·4	0·0	0·0

THE BAROMETER

Without actually measuring them men have been aware of the change of wind and rain, from the earliest times, long before weather-cocks and rain-gauges were invented. There was one change, however, connected with weather that they do not seem to have been aware of until an instrument for measuring it was invented, and that was the change of air pressure. The instrument is the Barometer.

In the middle of the seventeenth century Torricelli, an

Italian, discovered that if he stood a tube of mercury like that in Fig. 105 with its open end in a bowl of mercury the pressure of the atmosphere (represented by arrows) would not hold up a column of more than 29 or 30 inches.

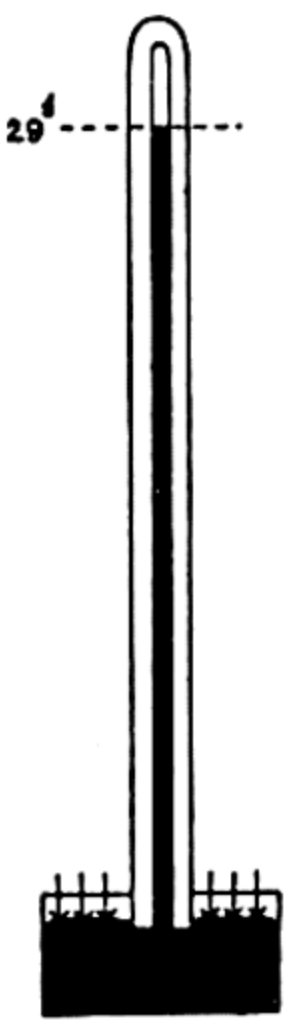


FIG. 105. — THE BAROMETER.

Later it was found that the height varied from time to time, and still later it was noticed that the change in height was associated with a change of weather. This led men to make barometers with the words "wet" and "dry" and so forth on them. But all that we can really say about the relation between the barometer and the weather is this: When the height of the column is falling, whether it be from 29 inches to 28 or from 31 to 30, it is probable that we shall have rain and unsettled weather; while if it is rising there is some hope of fine and settled weather. Some reasons for this will be considered later.

ALTITUDE AND PRESSURE

If a barometer that registers 29 inches on the surface be taken down a mine a thousand feet deep, it will register 30 inches on account of the extra air above it. If it is now brought to the surface and carried a thousand feet up on an adjacent mountain it will show only 28 inches, since there is a smaller column of air pressing down on it than there was at its original level. With care this experiment can be carried out in school, for it is possible to read the difference in pressure between the basement and the roof.

Before comparing the barometer readings of two stations the pressure must be "reduced to sea-level."

C. 15. A church tower is 100 feet high. What will the barometer read at the top if it is 29·6 inches on the ground?

The barometer of a school that stands at an altitude of 500 feet shows a height of 28·7 inches. What is the sea-level equivalent?

THE ANEROID BAROMETER

A most convenient form of barometer for carrying about is the aneroid, in which the column of mercury is dispensed with. Instead, there is a vacuum box which gets slightly larger or smaller according as the pressure of air decreases or increases, the movement being utilized to turn the finger on the dial.

An airman finds the height of his machine from the barometer he carries, and mountaineers can judge the height to which they have climbed by the same means; while the mining engineer uses an aneroid graduated to read 2,000 feet below sea-level.

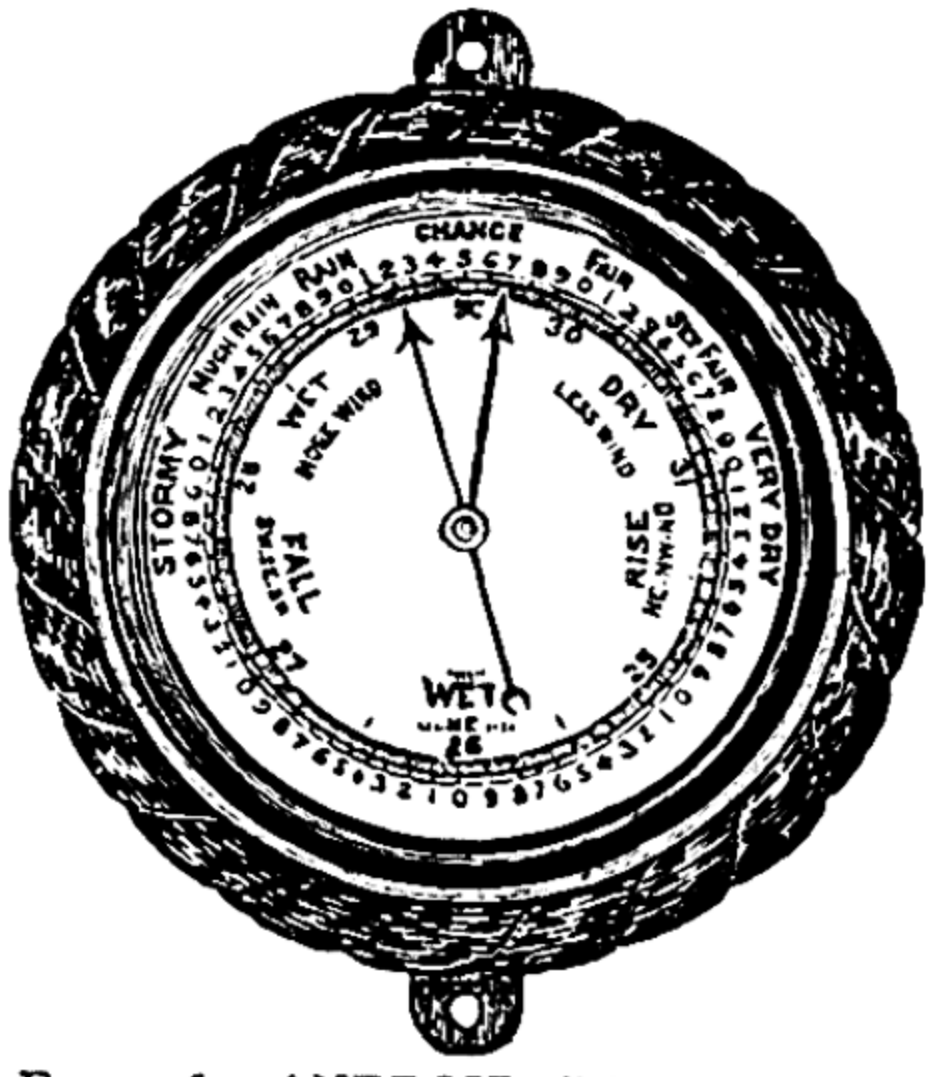


FIG. 106.—ANEROID BAROMETER.

MILLIBARS

In the Daily Weather Report the barometer readings are given not in inches but in millibars. A millibar (mb.) is one-thousandth of a "bar," a bar being a pressure corresponding to the height 29·5 inches in the mercury barometer. One millibar, therefore, corresponds to $\frac{29{\cdot}5}{1{,}000}$ inches (about $\frac{1}{34}$ in.).

C. 16. What height of mercury corresponds to the following pressures: 1,020 mb., 998 mb., 976 mb.?

C. 17. What pressure corresponds to the following heights in the mercury barometer:

30·0 inches, 30·1 inches, 30·2 inches? (See map of Australia, p. 106.)

Chapter Eight

THE WEATHER MAP

ISOBARS

IN the making of the weather map all the barometric readings are first increased to what they would be at sea-level on the scale of a thousand feet to an inch. Lines are then drawn through all places having the same sea-level pressure. These lines, called " isobars," form the most conspicuous feature on the weather map.

At the Meteorological Office in London telegrams are received each day from stations all over western Europe and Britain and from ships in the Atlantic giving, among other particulars, the sea-level barometer readings at each place.

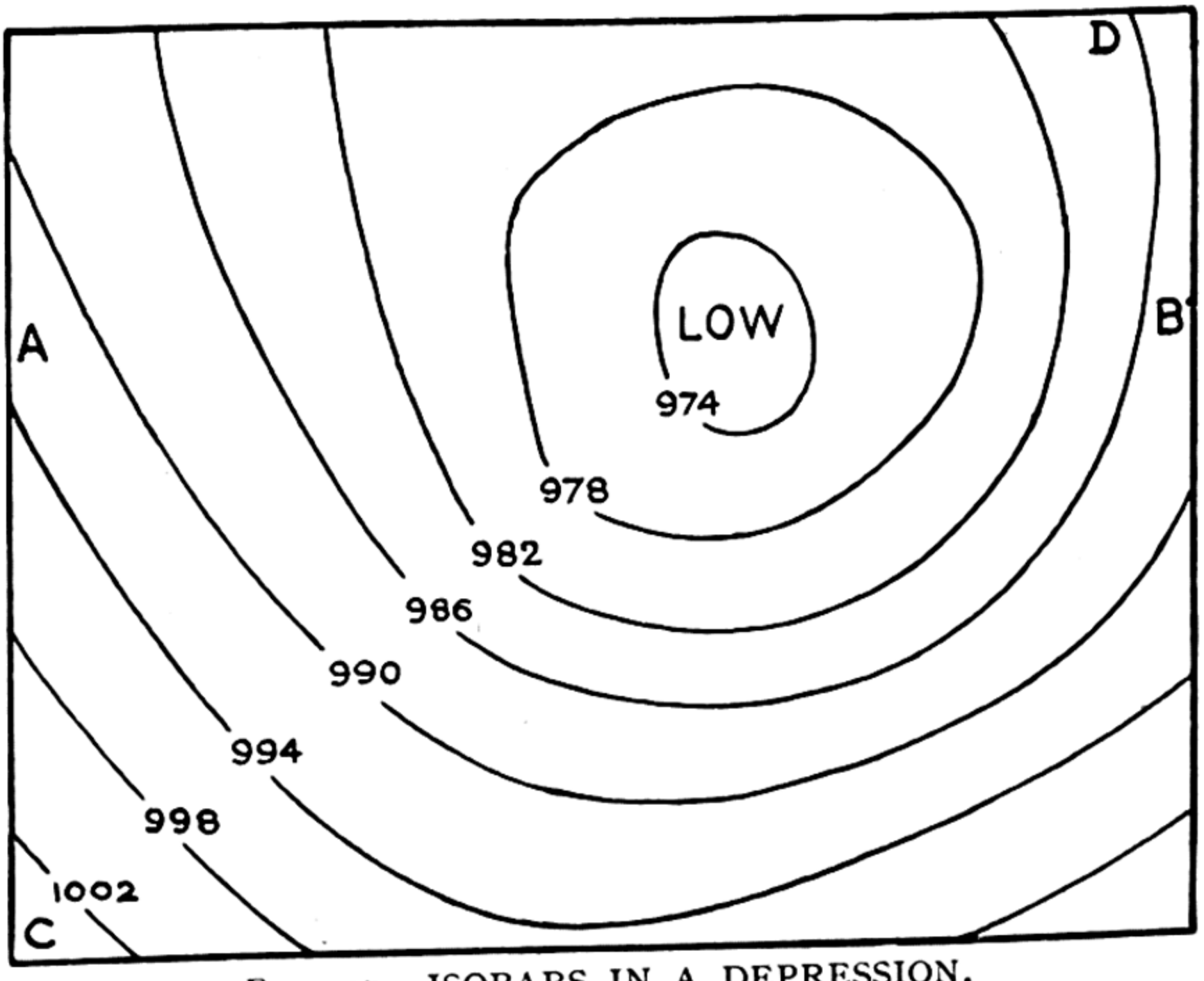


FIG. 107.—ISOBARS IN A DEPRESSION.

These readings (in millibars = mb.) are at once plotted on a large map and the isobars drawn at intervals of 4 millibars.

A DEPRESSION

Fig. 107 is taken from the same map as the wind-swirl in Fig. 99. On the full map it consists of a series of concentric isobars covering the whole of the British Isles. The pressure is "low" in the centre, where it is less than 974 mb., and rises steadily in all directions until it is over 1,000 mb. Such a

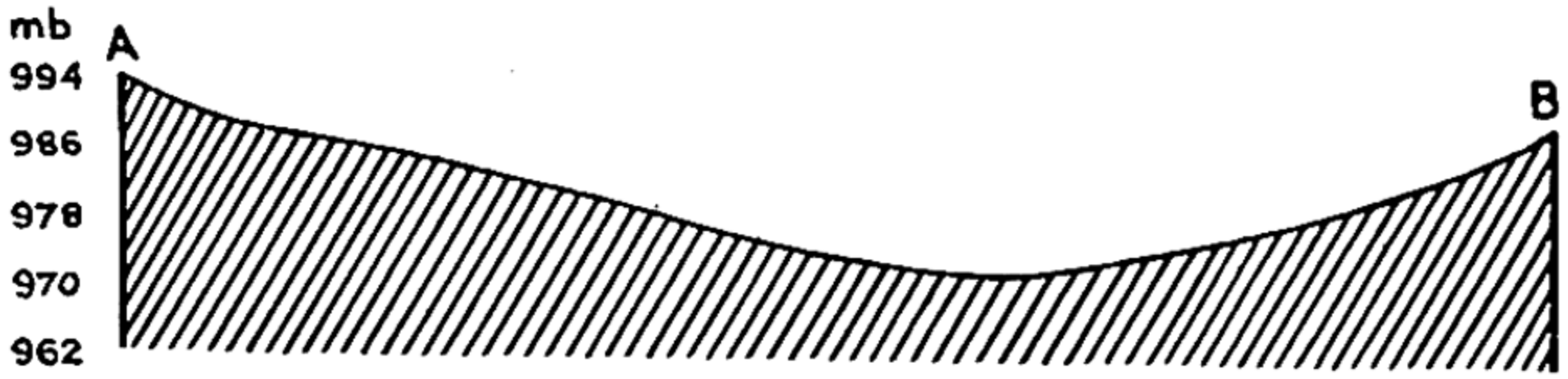


FIG. 108.—SECTION ACROSS THE DEPRESSION IN FIG. 107.

system, high on the circumference and low in the centre, is called a depression.

In Fig. 108 a section has been drawn across the depression between A and B.

C. 18. Draw a section between C and D. On paper with $\frac{1}{10}$-inch lines let each space equal 4 mb. With narrow-lined exercise paper each space can be 8 mb.

HOW THE BAROMETER "TELLS THE WEATHER"

AN EXPERIMENT

C. 19. (*a*) Copy Fig. 107 on a piece of tracing-paper and lay it on the map on page 95 with its centre over the cross in the west of Ireland. Read the pressure at Liverpool. Now move the tracing slowly eastward until the centre is over Anglesey.

How will a man in Liverpool know that the centre of a depression is approaching?

Continue moving the tracing eastward until the centre is over the cross on the border of the map.

What is the effect on the Liverpool barometer?

(*b*) Repeat the experiment, noting the pressure at Cardiff and Plymouth, Dublin and Hull, each time an isobar touches Liverpool.

(Make a table like the one for the winds.)

As will be seen later, a depression as it moves over Britain becomes less intense and finally disappears. The above exercise, however, helps us to understand its general effect on the barometer as it passes over a station.

THE SOUTHERN HEMISPHERE

In the southern hemisphere the winds associated with a depression move clockwise. This can be seen in the accompanying Australian weather report for January 5th, 1933. The "Low" over the centre of the continent is not so strongly marked as the one over Britain above, but the general clockwise trend of the winds is apparent if it is carefully examined.

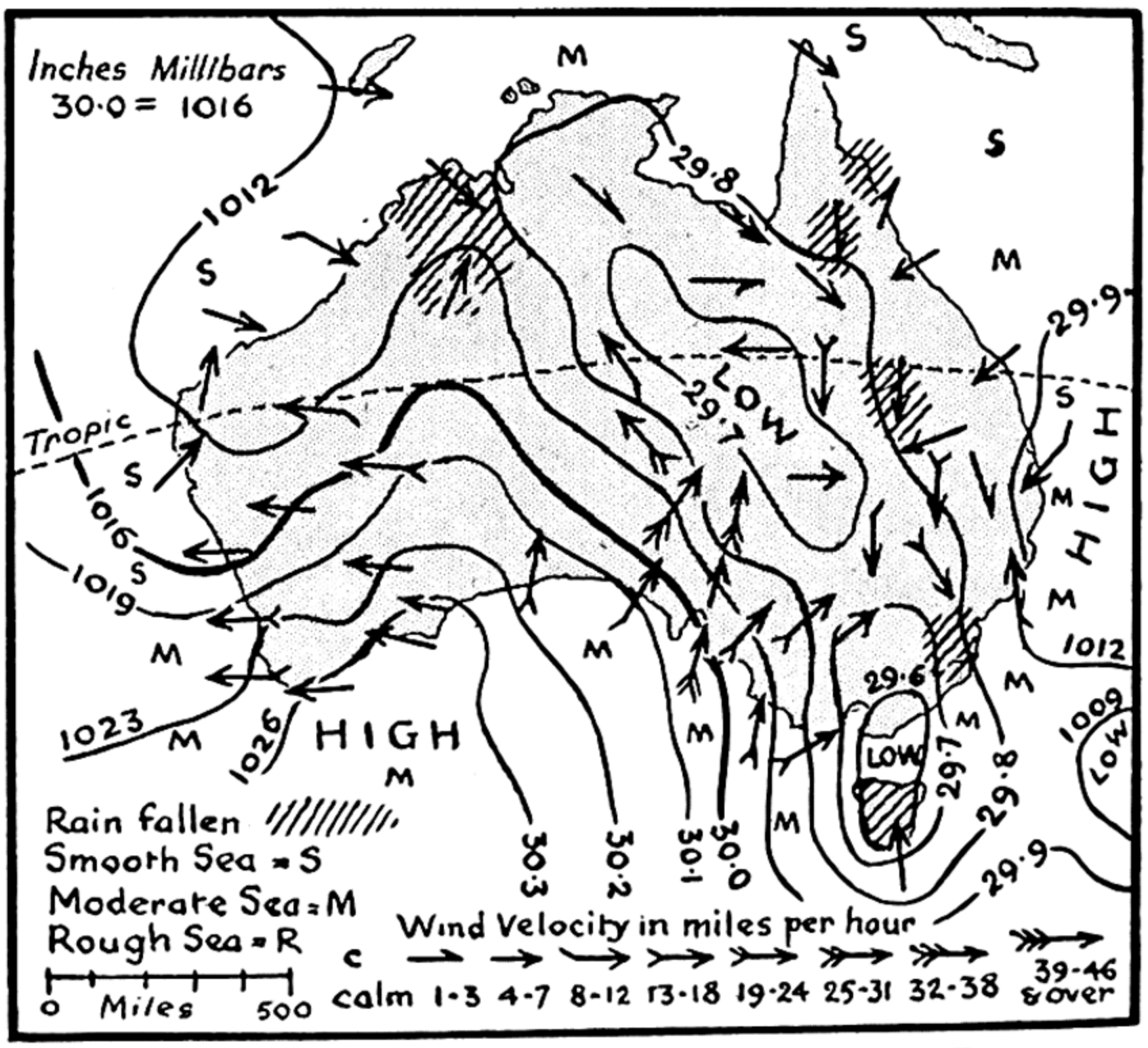


FIG. 109.—AN AUSTRALIAN WEATHER MAP.

THE BEAUFORT SCALE

The force of the wind is represented by the number of "feathers" in the arrows that show its direction, the numbers

ranging from 1 to 12. This is known as the Beaufort Scale, after Admiral Beaufort its originator.

ANTICYCLONES

At one time the low-pressure system to which we now give the name of depression was called a cyclone, and a high-pressure system became, by contrast, an anticyclone. As certain tropical storms, however, are called cyclones, "Depression" was introduced to avoid confusion.

THE DAILY WEATHER REPORT[1]

Figs. 111, 112, and 113 are pieces of the weather map giving conditions on Friday at 6 p.m. and on Saturday at 7 a.m. and 6 p.m.

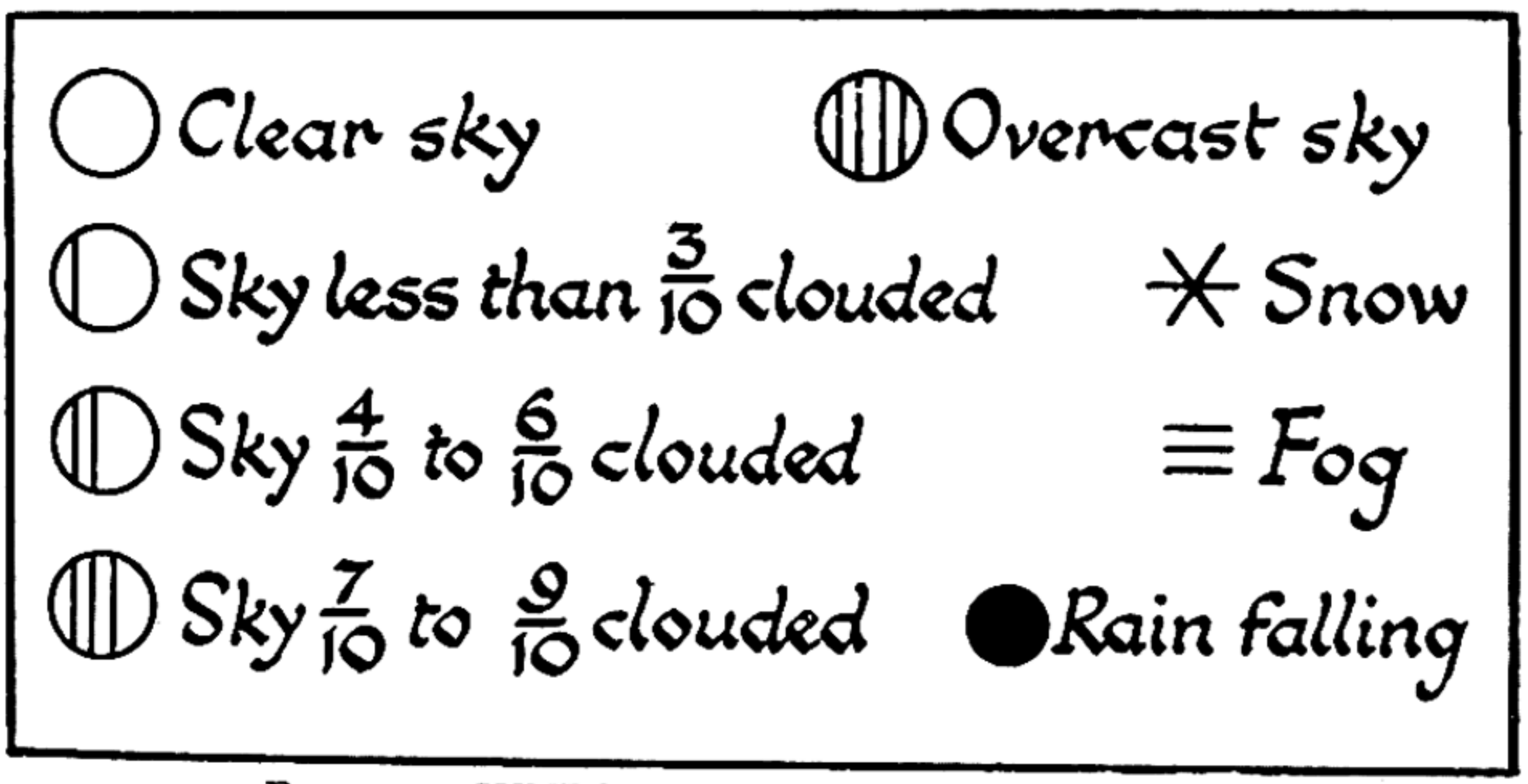


FIG. 110.—SYMBOLS ON THE WEATHER MAP.

In the first there is a depression centred over the S.W. of Ireland. In the second the centre has moved to the Irish Sea, while in the third it has reached the North Sea.

C. 20. Mark the winds for Friday at 6 p.m. on a tracing-paper. Add others to complete the swirl. Lay the tracing on the succeeding maps and judge whether the general direction of the winds in the depression is the same.

[1] Since the weather map brings together a number of distributions (temperature, rainfall, etc.) and allows them all to be seen at once in relation to one another, it is spoken of as the Synoptic Chart.

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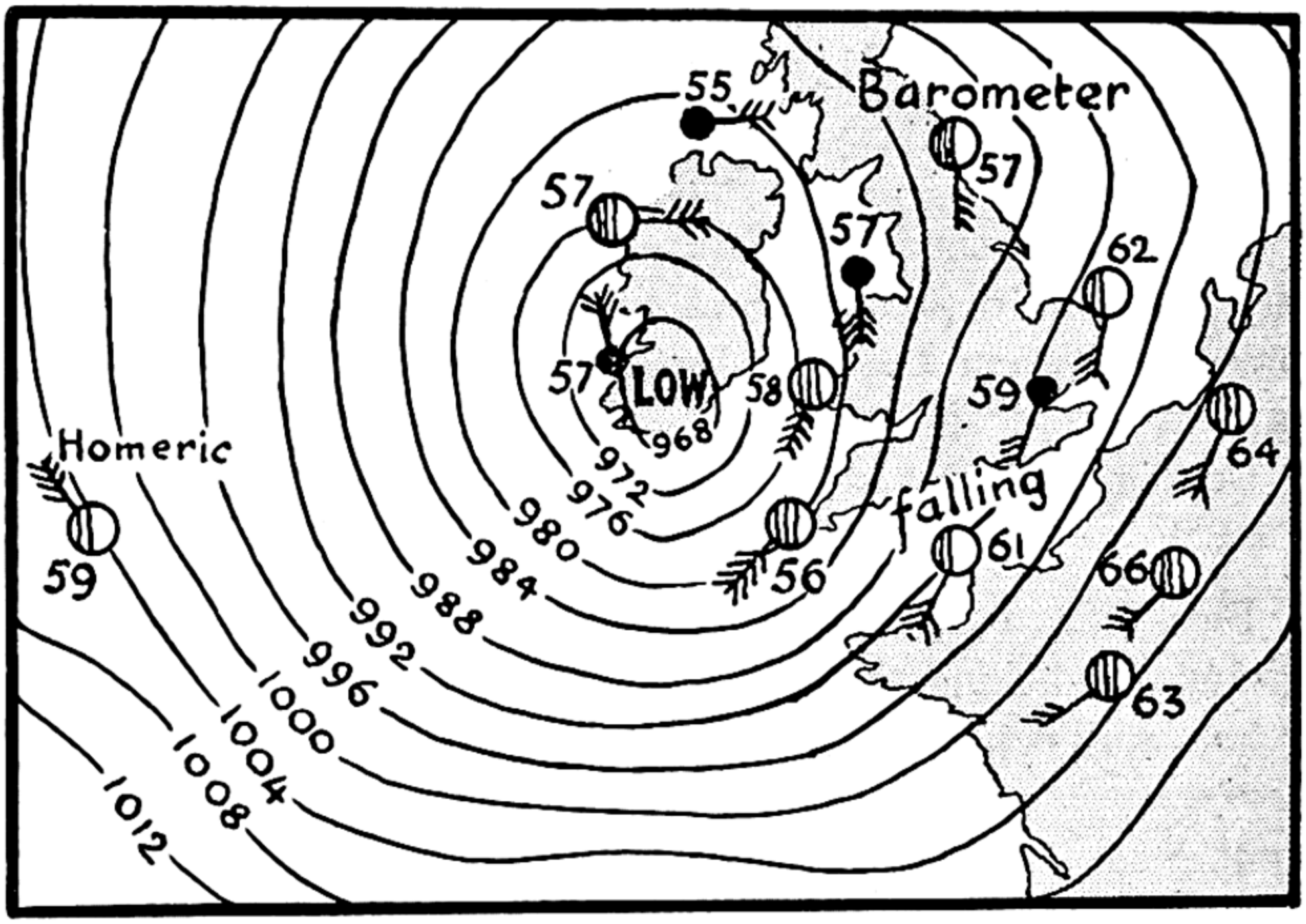


FIG. 111.—FRIDAY, 6 P.M.

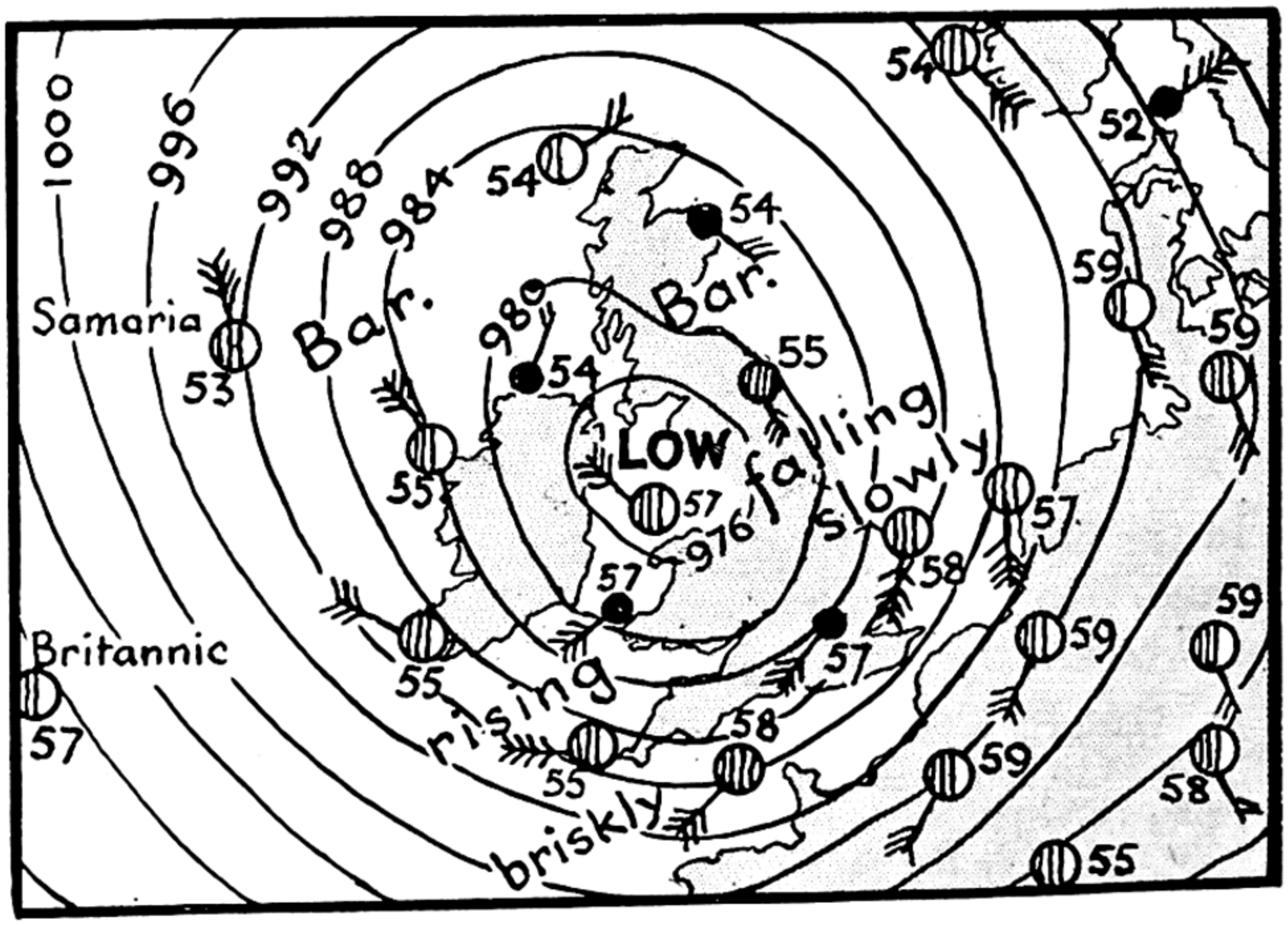


FIG. 112.—SATURDAY, 7 A.M.

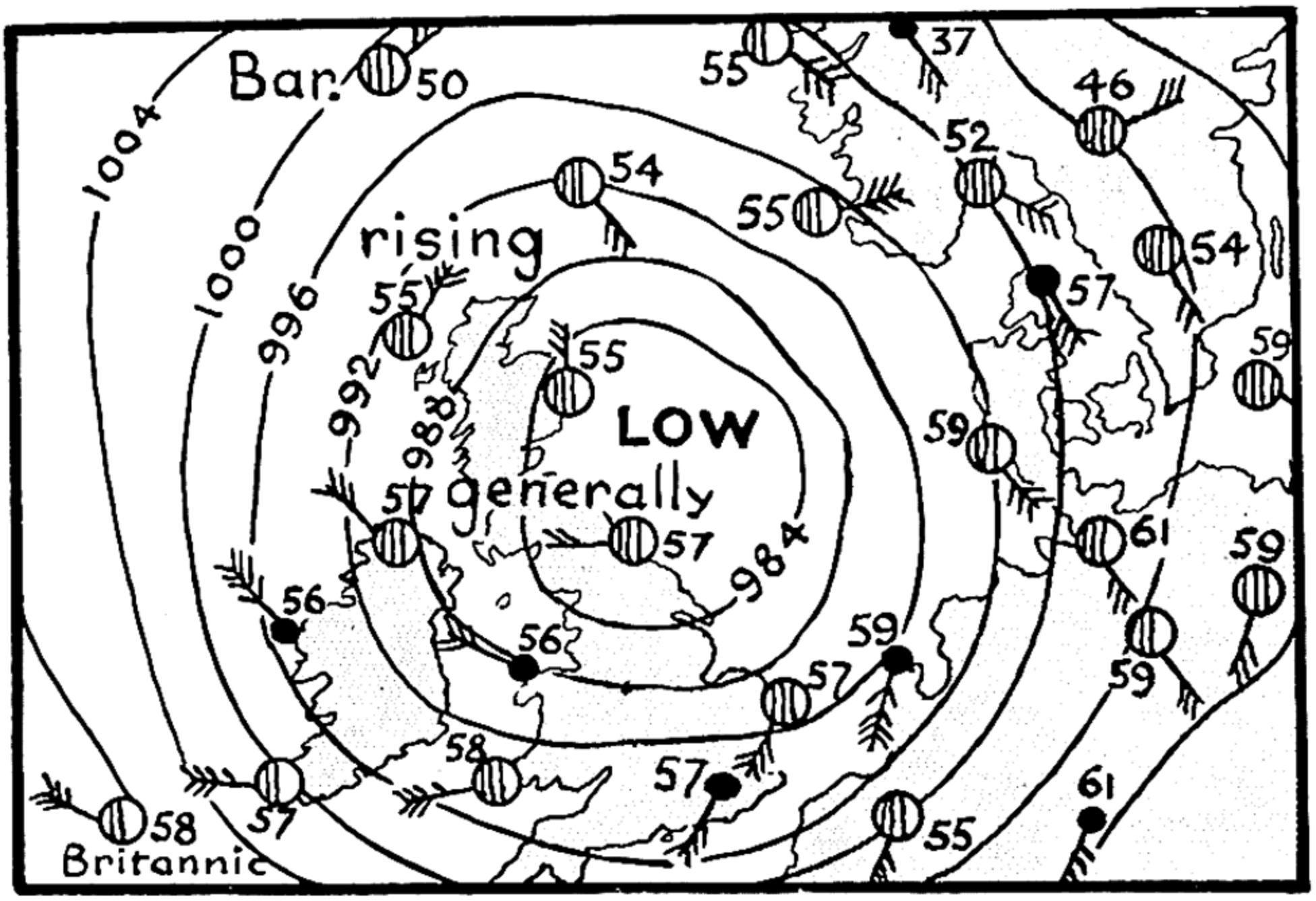


FIG. 113.—SATURDAY, 6 P.M.

D. 1. The weather conditions for Newcastle on the Friday map are:

Pressure, 986 mb.
Wind. Direction: South
Force 3.
Temperature, 57° F.
Sky more than three-quarters clouded.

Check these statements with the map.

D. 2. Write down the conditions for Saturday (*a*) at 7 a.m., (*b*) at 6 p.m.

D. 3. Check the following table of wind and pressure with the map:

	Friday, 6 p.m.	Saturday, 7 a.m.	Saturday, 6 p.m.
Dublin .	S.E. 976 mb.	N.W. 978 mb.	N.W. 990 mb.

D. 4. Make a similar table to show wind and pressure changes at (*a*) London and Belfast, (*b*) Edinburgh and Plymouth, (*c*) Hull and Newcastle.

C. 21. Trace the numbers indicating temperature on Friday at 6 p.m. and draw a line dividing places with temperatures below 60° F. from those where it is above.

C. 22. Draw the corresponding line for 62° F.

D. 5. Notice that the centre isobar in the first map is 968 mb., while in the third it is 984. At the same time the isobars have got farther apart. This shows that the depression is filling up.

Draw a section across the middle of each of the three.

FIG. 114.—WEDNESDAY, 1 P.M.

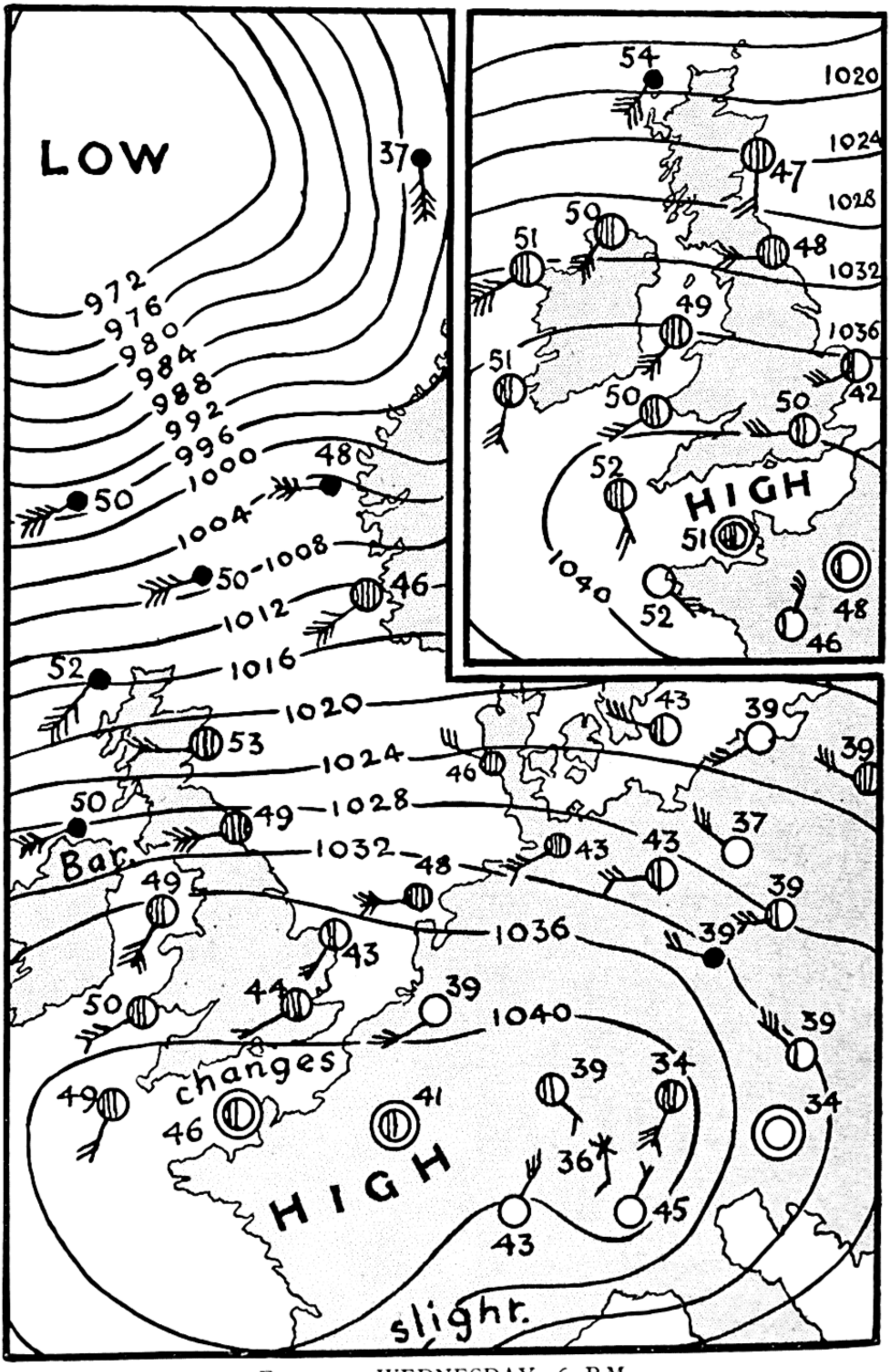


FIG. 114.—WEDNESDAY, 6 P.M.

THE ANTICYCLONE AND THE WEATHER

Fig. 114 shows a high-pressure area over the English Channel (Wednesday, 1 p.m.) which by 6 p.m. has moved slightly to the south-east. By Thursday at 7 a.m. it has moved considerably further in the same direction.

In each map the central area is enclosed by isobar 1,040, and the numbers run down from this. The effect of the movement of the " High " on the barometer can be seen by the word " falling."

Notice that the winds move clockwise and away from the centre, and that in the centre itself they are very light, a number of stations reporting " calm."

D. 6. Draw a N.–S. pressure section across the middle of the map.
(*a*) Wednesday, 1 p.m.
(*b*) Wednesday, 6 p.m.
(*c*) Thursday, 7 a.m.

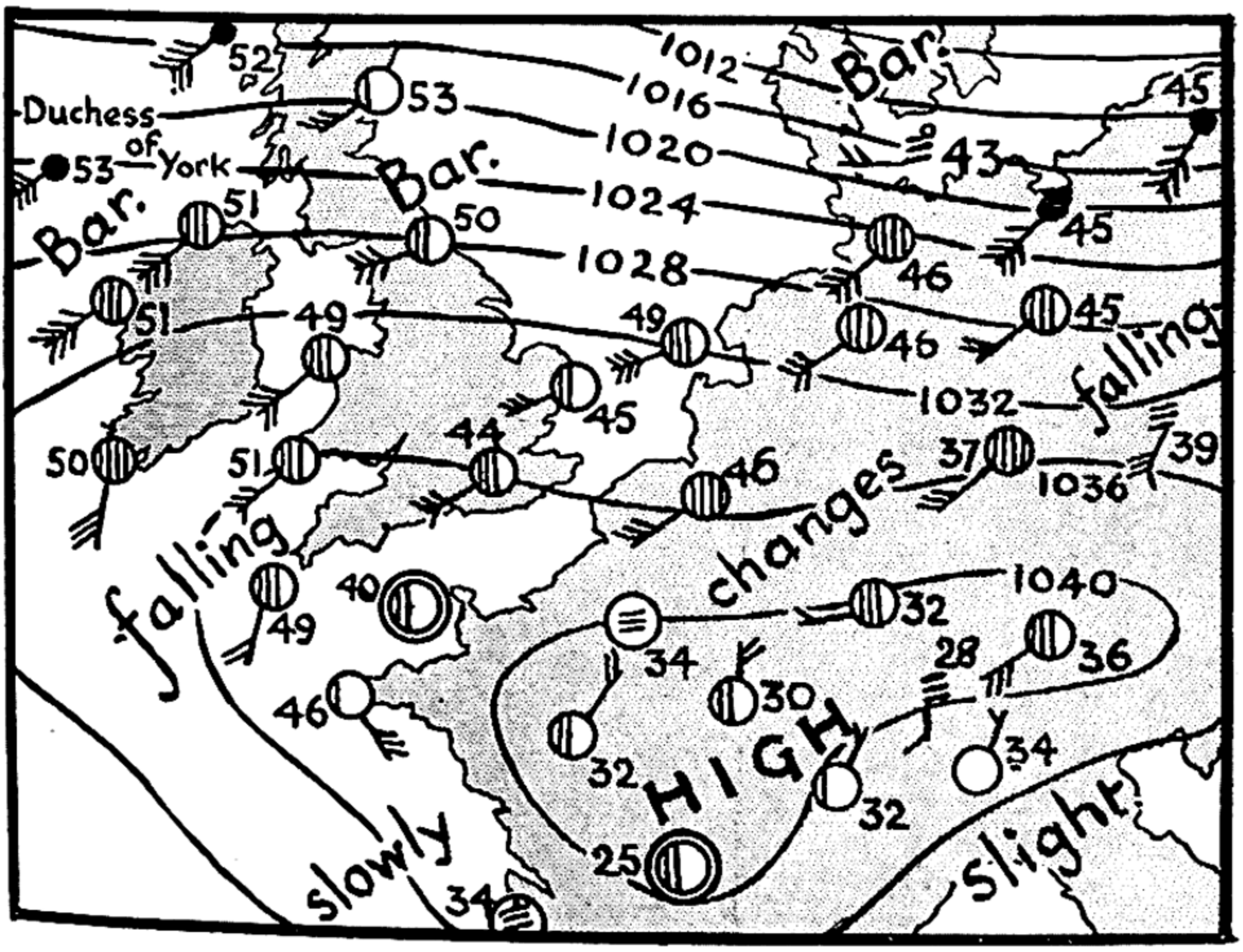


FIG. 115.—THURSDAY, 7 A.M.

HIGH- AND LOW-PRESSURE SYSTEMS

Although it is convenient to study first depressions and then anticyclones, it would be wrong to think of them as separate phenomena, for they are very intimately connected; and when we look at a map showing both types it is difficult to draw a line between them, as they merge gradually into each other. Wind movement is generally from areas of high pressure to areas of low pressure; this is well illustrated by the winds to the west of Scotland in Fig. 114.

D. 7. Draw a N.–S. section through the high and low centres. (Fig. 114.)

D. 8. If the maps on pages 108–111 be regarded as typical, what are the general contrasts between high- and low-pressure areas in (*a*) wind force, (*b*) amount of cloud, and (*c*) rainfall.

C. 23. Trace the isobar enclosing the "Low" in the middle of the continent in Fig. 109. Add the winds associated with it.

C. 24. Make a table from the Australian map, showing the relation between inches and millibars.

TEMPERATURE MAPS

ON page 109 there appears this exercise: Trace the numbers indicating temperatures on a certain map and draw a line dividing places with temperatures below 60° F. from those where it is above.

This has been done in Fig. 116, the line passing proportionately nearer 61 than 56, nearer 59 than 64, and nearer 62 than 57. This, as far as we can judge, gives all places on the dividing line a temperature of 60°. Such a line is called an isotherm.

D. 8. Mark the temperatures on a tracing-paper, and draw these isotherms:

(*a*) Thursday 7 a.m. 40°, 50°.

(*b*) Wednesday 6 p.m. 40°, 45°, 50°.

(*c*) Wednesday 1 p.m. 50°, 51°, 49°, 48°.

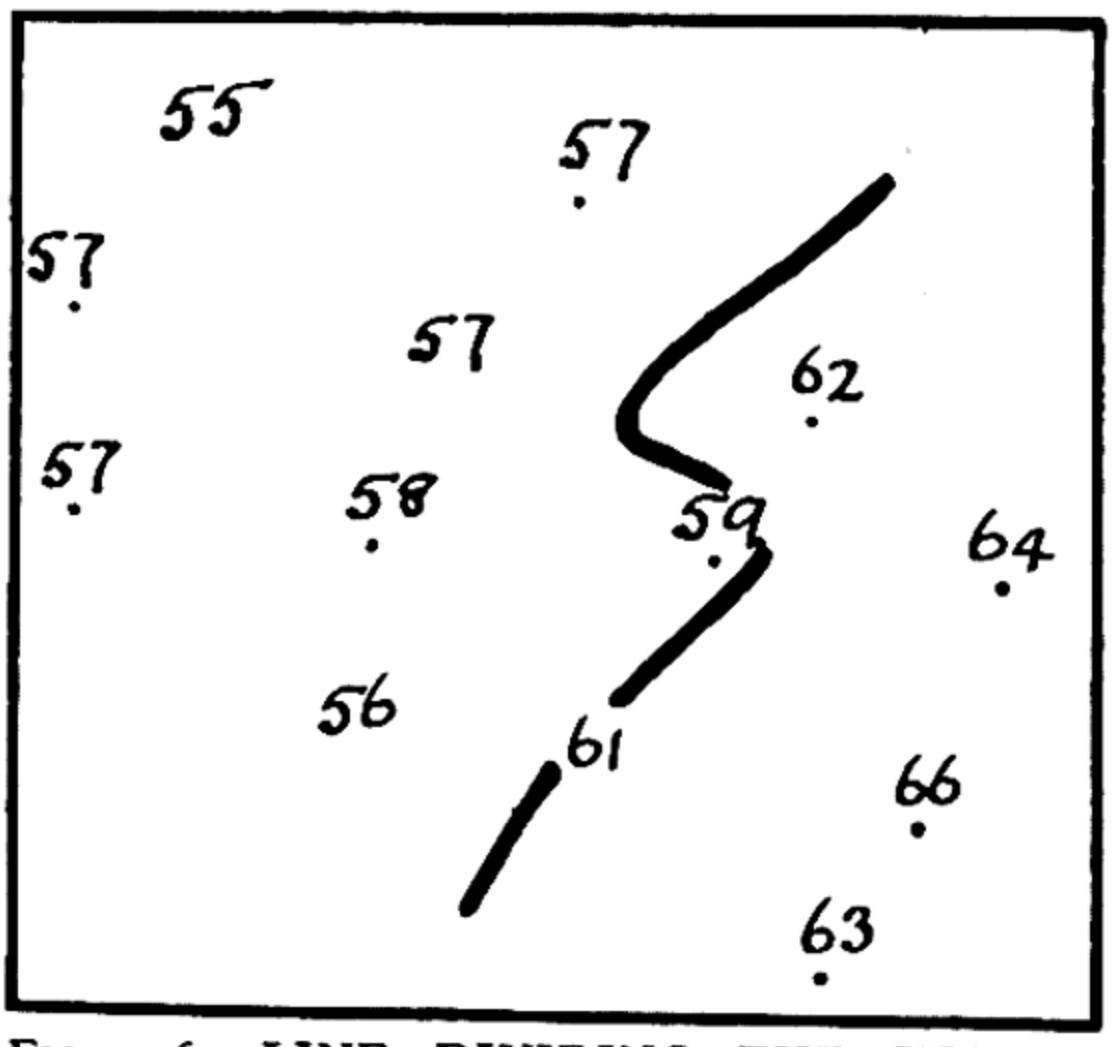


FIG. 116.—LINE DIVIDING THE HIGHER AND LOWER TEMPERATURES.

TWO TYPES OF ISOTHERM

For some purposes it is necessary to know what is the actual course of an isotherm across a country or a continent, but for other purposes we calculate what the course would be if all the mountains and hills were planed down to sea-level. The

rate at which the temperature falls as we go up a mountain varies somewhat from place to place, but in drawing isotherms it is assumed to be 1° F. for every 300 feet of ascent. If, therefore, a station 300 feet above sea-level has a temperature of 56°, it is plotted on the map as being 56° + 1° or 57°, while if its elevation is 600 feet it is plotted as 56° + 2° or 58°. The first type are called the actual or surface isotherms. Those of the second type are sea-level isotherms.

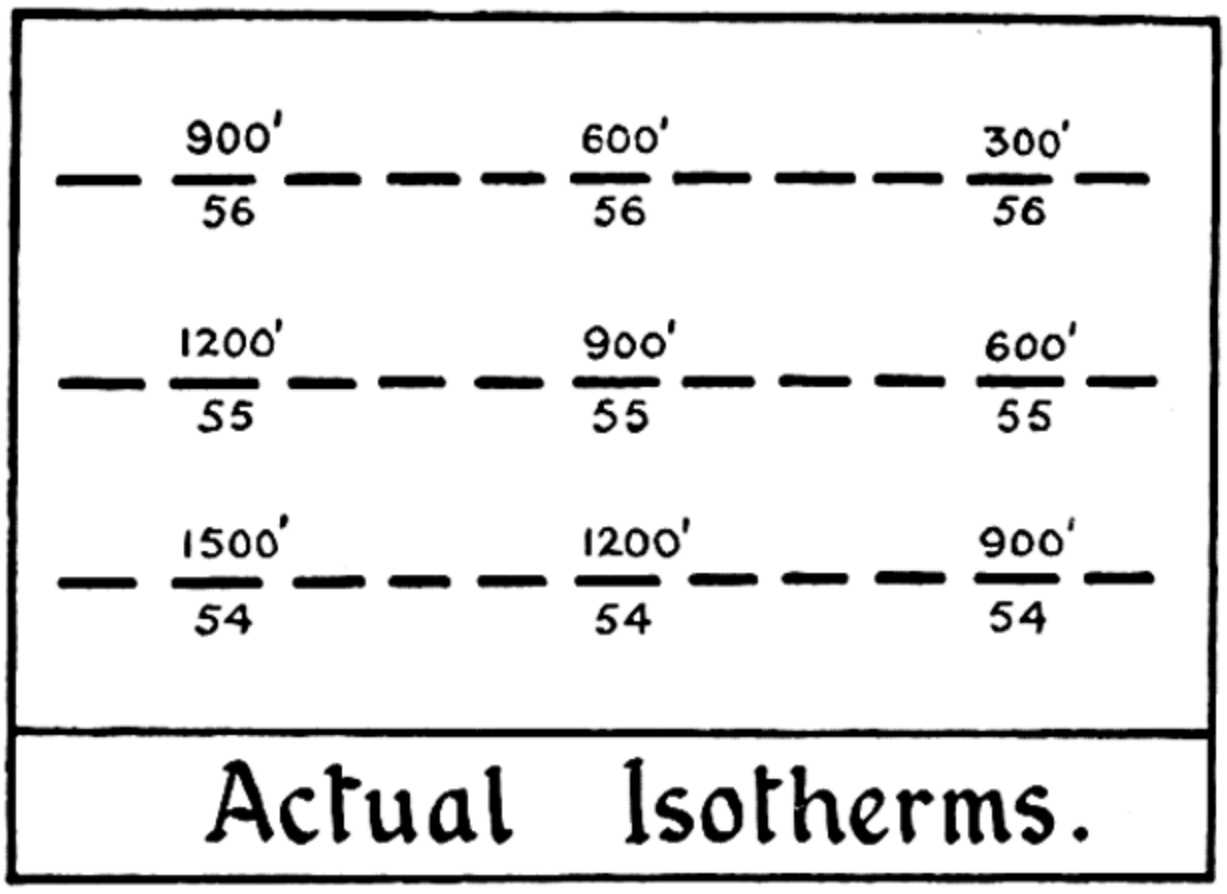


FIG. 117.

In the first diagram, with its nine stations, surface isotherms have been drawn at 54°, 55°, and 56°.

In the second diagram the figures have been altered to their sea-level equivalents, and lines drawn at 57°, 58°, and 59°.

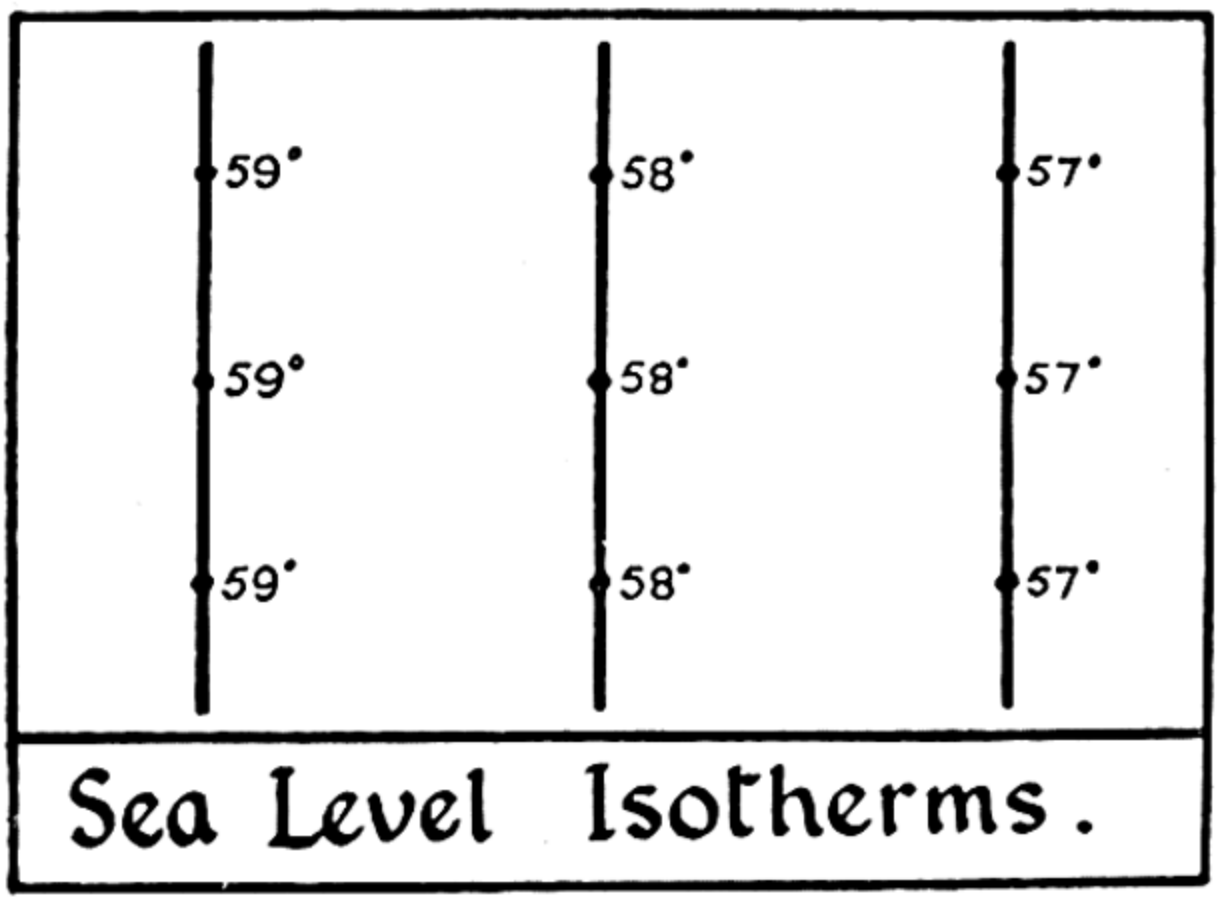


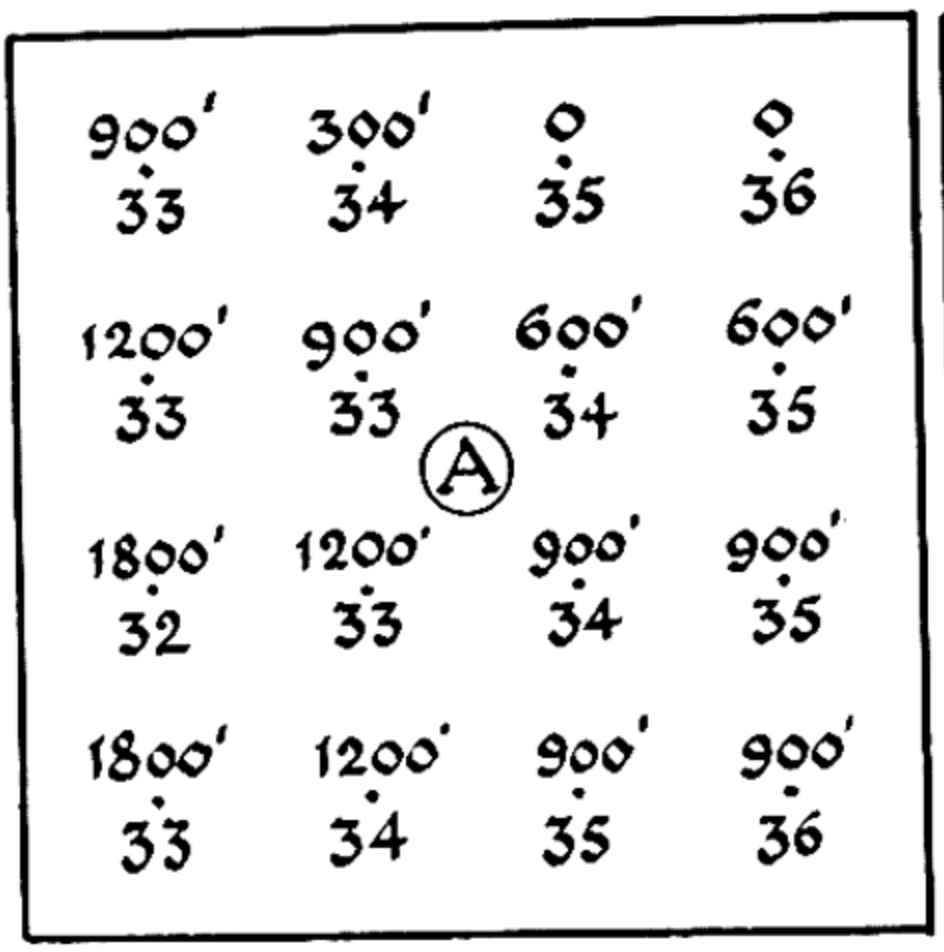
FIG. 118.

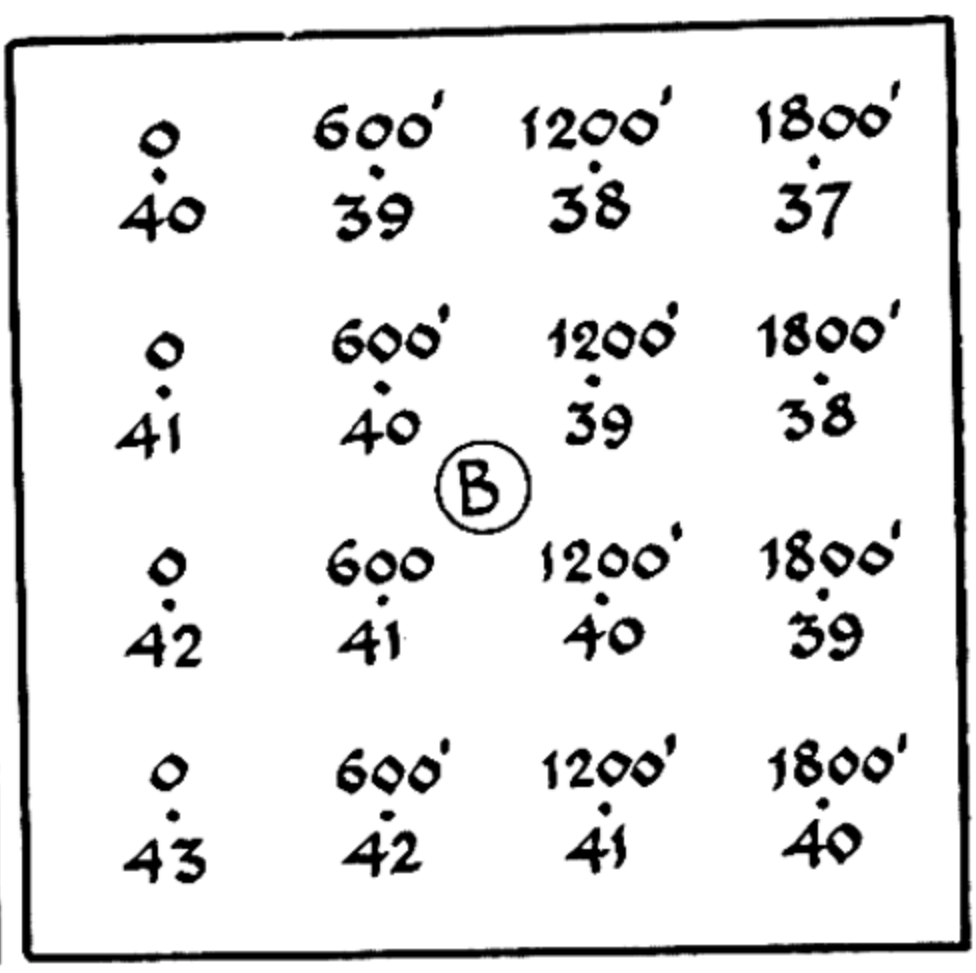
ISOTHERM EXERCISES

In the following exercises the temperatures of a number of imaginary stations are given, with their heights above sea-level. In practice, of course, stations are never spaced regularly like this, but are spread over a country in a very uneven fashion.

C. 25. Copy the temperatures in A (Fig. 119) and draw surface isotherms for 32°, 33°, 34°, and 35°.

C. 26. Convert the temperatures in A to what they would be at sea-level, and draw isotherms for 35°, 36°, 37°, and 39°.





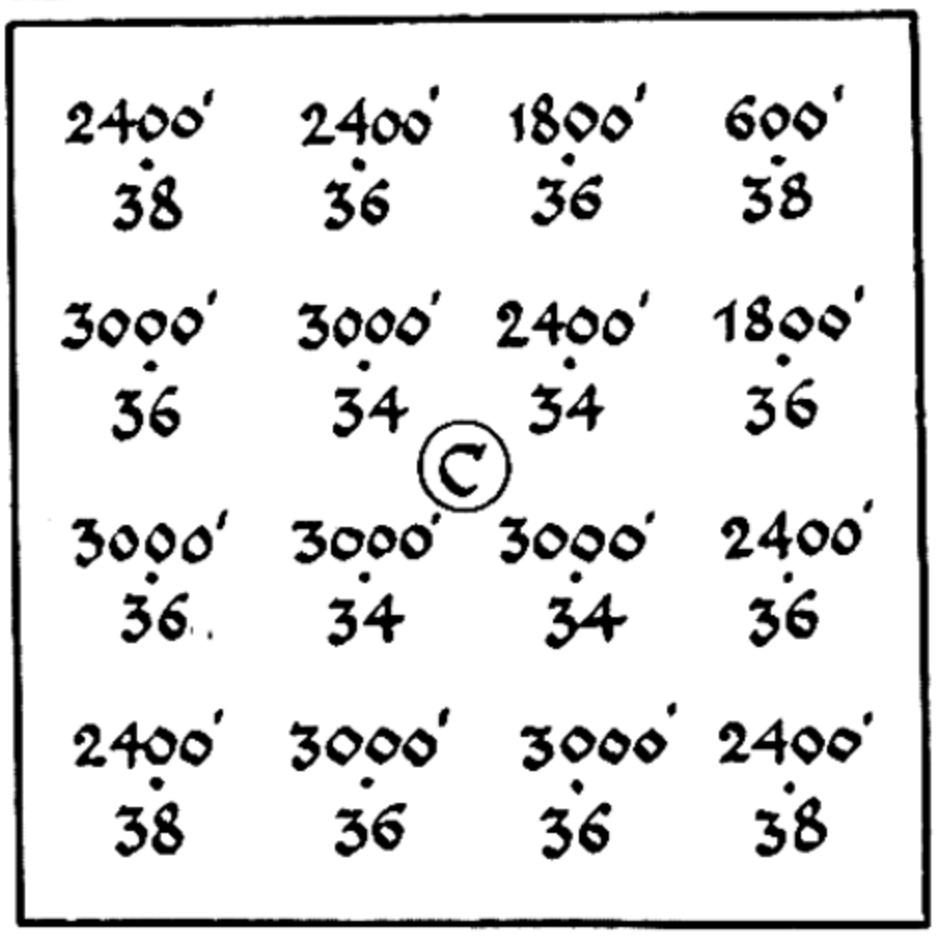


FIG. 119.

C. 27. Copy the temperatures in B and draw actual isotherms for 37°, 38°, etc.

C. 28. Convert the temperatures in B to their sea-level equivalents and draw isotherms for 40°, 41°, etc.

C. 29. Copy the temperatures in C and draw surface isotherm.

C. 30. Convert the temperatures in C to their sea-level equivalents and draw the isotherms.

READING THE SEA-LEVEL ISOTHERM MAPS OF THE WORLD

ISOTHERM 40° FOR JANUARY

We will consider first isotherm 40° F. on the January map. This passes through Britain and consequently enables us to judge to some extent the winter temperatures in other parts of the northern hemisphere by comparison with our own. We must not try to make too full a comparison, however, as, with only one isotherm to help us, we may fall into error.

The northern part of the map, marked off by isotherm 40° F., is colder than the southern.

The eastern side of Great Britain is on the colder side of the line, while Ireland is on the warmer side. Valentia Island is farther from the line than any other part of Ireland, and

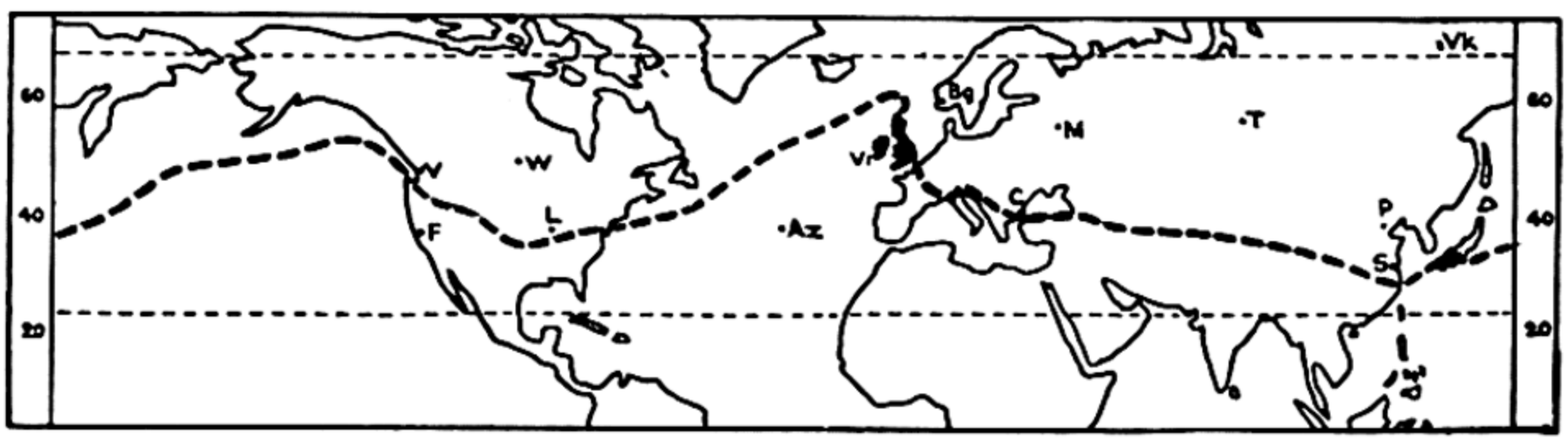


FIG. 120.—SEA-LEVEL ISOTHERM 40° F. FOR JANUARY.

Az = Azores.	M = Moscow.	VI = Valentia Is.
Bg = Bergen.	P = Pekin.	Vk = Verkhoyansk.
C = Constantinople.	S = Shanghai.	W = Winnipeg.
F = San Francisco.	T = Tomsk.	
L = St. Louis (U.S.A.).	V = Vancouver.	

is therefore, probably, the warmest part of the British Isles in the winter.

The Shetland Isles appear to be as warm as Constantinople and warmer than Winnipeg, or Pekin, or even Shanghai, although these places lie much farther south.

C. 31. Describe the course of the January isotherm 40° from the map, saying where it goes northward and where southward. Make comparisons with places in the British Isles or Eurasia in the same latitudes.

C. 32. Lay a ruler along parallel 40°. Where are the colder areas, on land or on sea? Which coasts of North America and Eurasia are warmer, the east or the west?

SEA-LEVEL ISOTHERM 60° F. FOR JULY

Isotherm 60° F. for July runs across Britain, so that we may now compare its temperature in the warmest month of the year with the temperatures in other parts of the world.

C. 33. Lay a ruler first along parallel 40° and then along parallel 60°. Where are the warmest parts of the world along these parallels,

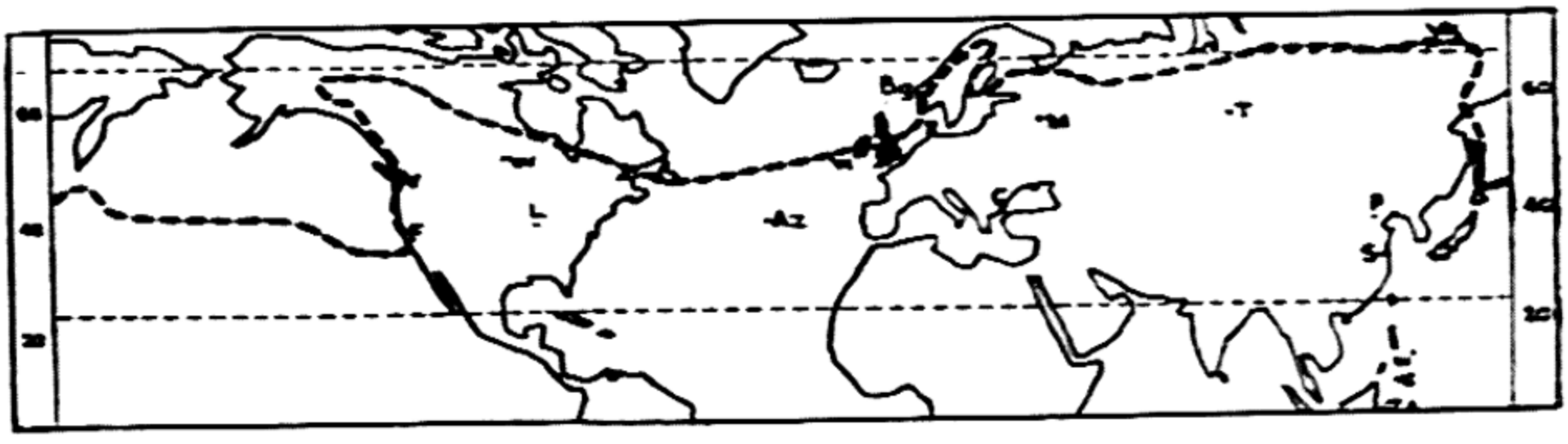


FIG. 121.—SEA-LEVEL ISOTHERM 60°F. FOR JULY.

Az = Azores.
Bg = Bergen.
C = Constantinople.
F = San Francisco.
L = St. Louis (U.S.A.).
M = Moscow.
P = Pekin.
S = Shanghai.
T = Tomsk.
V = Vancouver.
Vl = Valentia Is.
Vk = Verkhoyansk.
W = Winnipeg.

over the land or over the sea? Which are the cooler coasts of North America and Eurasia?

C. 34. Describe the course of isotherm 60° from the western side of the map to the eastern. Where does it go farthest north and farthest south? Make comparisons with places in the British Isles or Eurasia in the same latitude.

COMBINED EXERCISES

D. 9. The Azores and St. Louis lie, roughly, in the same latitude. Which has the bigger difference between summer and winter temperatures?

D. 10. Edinburgh, Moscow, and Tomsk lie, roughly, in the same latitude. Which has the biggest difference in temperature between summer and winter; which has the least?

D. 11. In January Verkhoyansk is the coldest village in the world, with an average temperature of 60° below zero. Compare its annual range with that of Newcastle.

D. 12 What conclusions can you draw from the two maps about the effect of the sea on the temperature in summer and winter?

Chapter Ten

THE WINDS OF THE WORLD

IF the world were covered with water the arrangement of the winds at certain periods of the year would probably be that suggested in the diagram. Over the Equator are the Doldrums, regions of very light winds and very heavy rains where ships in the days of sail were becalmed. Blowing towards the Equator from either side are the N.E. and S.E. Trades. In the neighbourhood of the tropics are regions of calm that are rainless, and beyond these the "anti-trades" or "westerlies" such as blow in Britain. These are not steady winds like the Trades; they move round the Earth in a series of swirls or eddies that the weather report speaks of almost daily as "depressions." The Doldrums belt moves north and south of the Equator with the sun, the other belts swinging with it. The result of this is that a place may be in one belt during the winter months and in the next belt during the summer.[1]

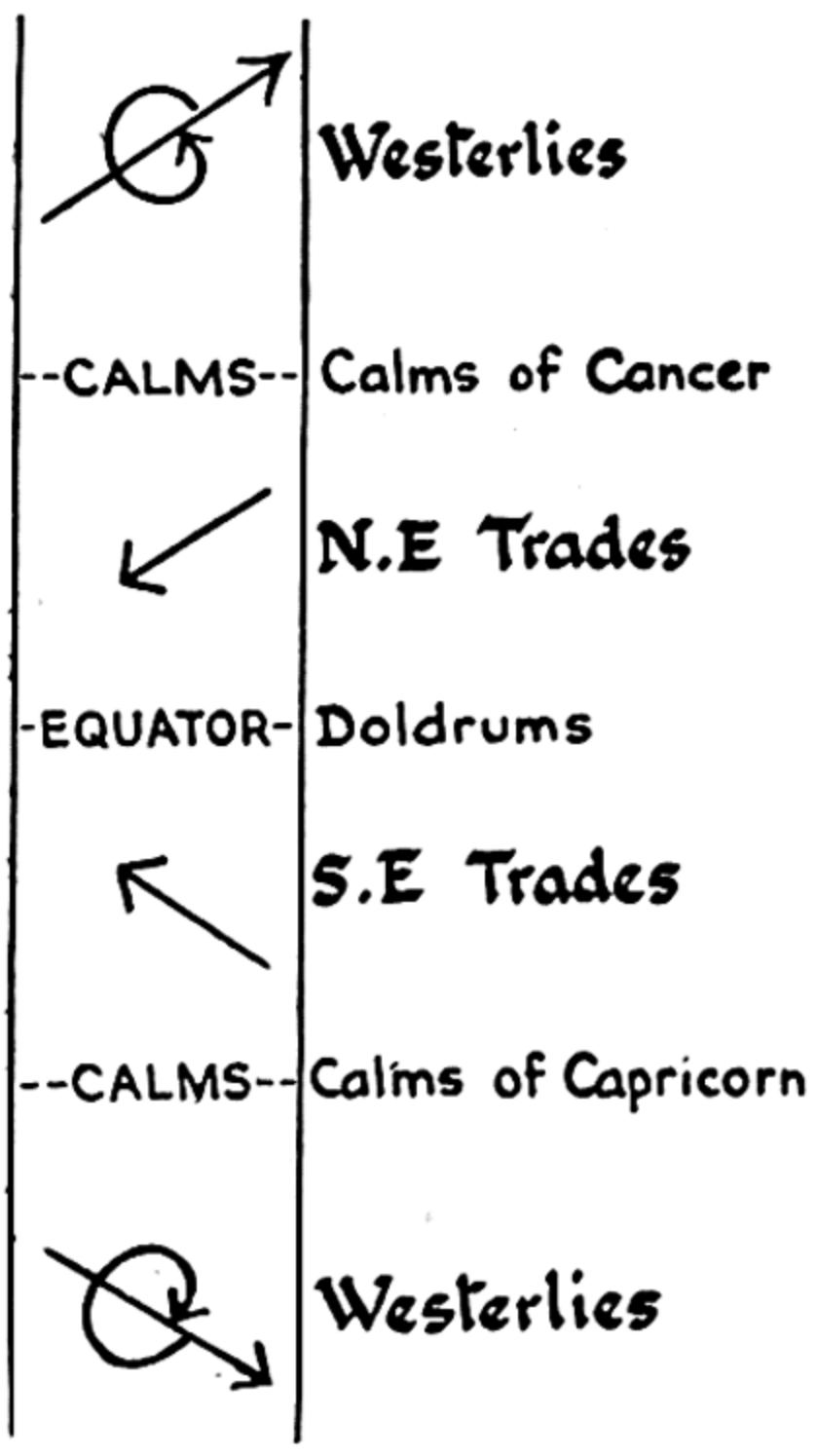


FIG. 122.—DIAGRAM OF THE WINDS OF THE WORLD.

[1] The wind and rainfall belts are, of course, very closely related.

Over the oceans this system does to some extent hold, but the existence of the great land masses greatly modifies it. Over Asia and the surrounding seas it is completely displaced by the monsoon system, where the prevailing winds are from the ocean in summer and from the centre of the continent in the winter.

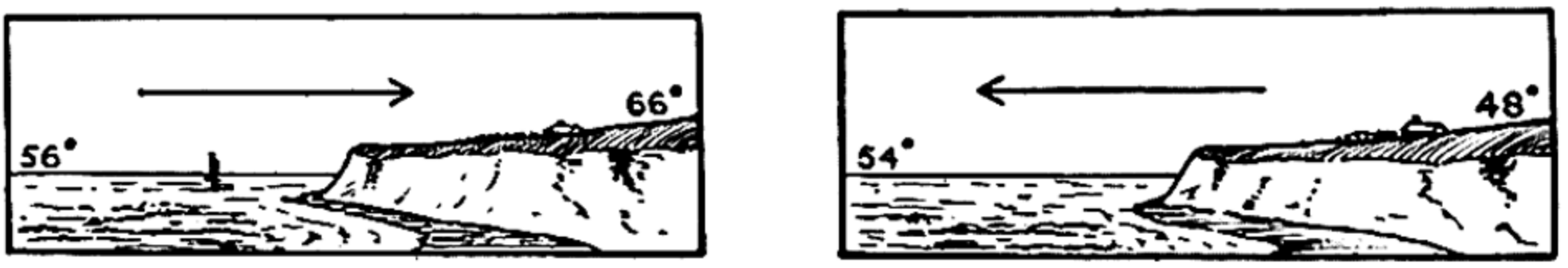
C. 35. Draw the January and July wind-roses for the following, using the figures in the Tables. In each case say to which belt or system it belongs :
(*a*) Greenwich, (*b*) Bombay, (*c*) Grenada, (*d*) Vladivostock, (*e*) the Bluff (N.Z.), (*f*) St. Helena.

THE MONSOONS

The monsoons of S.E. Asia may be regarded as land and sea breezes on a vast scale, the land mass of Asia being much hotter than the sea in summer and the sea being the warmer in winter.

LAND AND SEA BREEZES

In hot weather the surface of a country may become so heated in comparison with the surrounding sea that a wind is set up which blows from the cooler sea to the warmer land.



DAY. SEA BREEZE. NIGHT. LAND BREEZE.

FIG. 123.

We can see the same sort of thing happening on a much smaller scale in an ordinary room at home with a good fire burning; the smoke from a cigarette held near the floor travels towards the fire and up the chimney.

When the sun goes down the land loses its heat rapidly and in a few hours has cooled so much that of the two the sea is the warmer. Then the wind begins to move from the land to the sea.

The tables give the winds for each hour on two days in Manila, together with the times of sunrise and sunset.

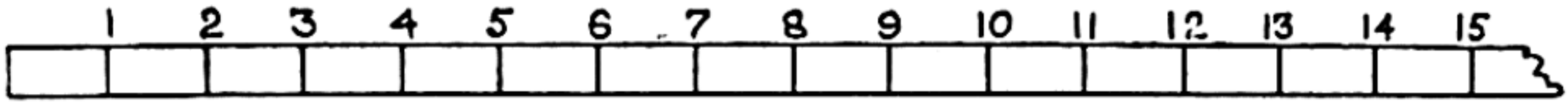


FIG. 124.—A TWENTY-FOUR HOUR WIND RECORD.

C. 36. Draw a rectangle 6 inches long and $\frac{1}{8}$ inch deep to represent a day. Divide it into 24 hours and shade the night-time. Over each hour write "L" for land breeze, or "S" for sea breeze for September 1st. When does the change-over occur?

C. 37. Make a similar diagram for July 11th.

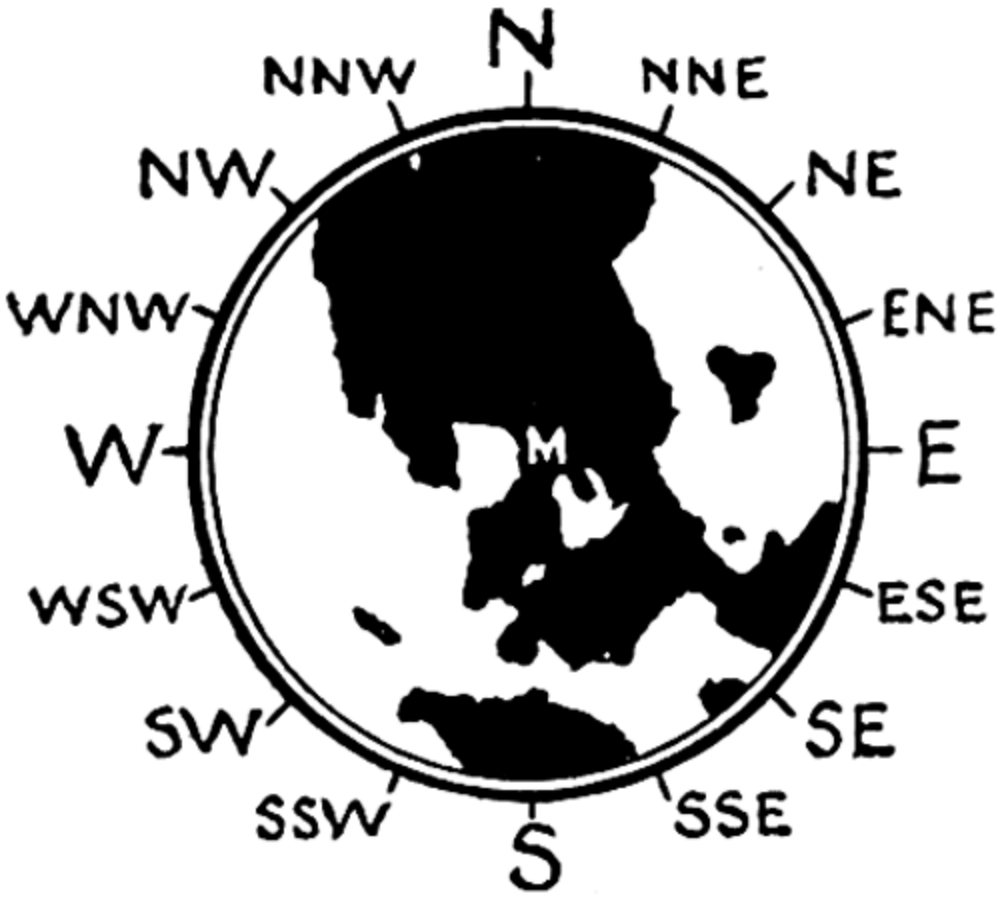


FIG. 125.—THE POSITION OF MANILA.

Manila Winds July 11th, 1926. Sunrise 0536. Sunset 1834.

1	2	3	4	5	6	7	8	9	10	11	12
NE	NE	NE	NE	NE	Calm	NE	Calm	WSW	WSW	WSW	WSW
13	14	15	16	17	18	19	20	21	22	23	24
SW	SW	WSW	SW	SW	SW	SSE	E	ESE	SE	ESE	SE

Manila Winds September 1st, 1926. Sunrise 0554. Sunset 1812.

1	2	3	4	5	6	7	8	9	10	11	12
SE	E	SE	SE	E	E	E	Calm	S	S	SW	SW
13	14	15	16	17	18	19	20	21	22	23	24
SW	WSW	SW	SW	SW	SW	SW	SW	NE	NNE	E	ESE

DAILY WEATHER RECORDS

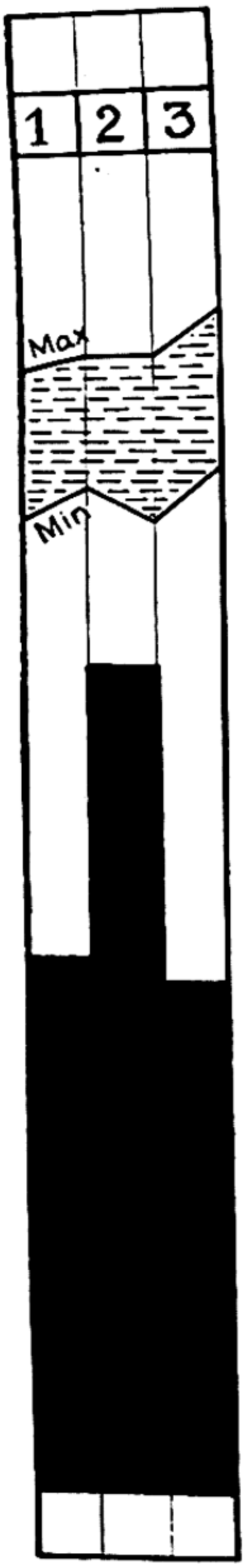


FIG. 126. — THREE DAYS' WEATHER.

ON pages 188–193 are some daily weather records from various parts of the world. They cannot all be strictly compared with those of this country because the times at which they are taken and the methods of recording are different. It is possible, however, to make some very interesting and useful graphs from them.

As far as possible they are all taken for the same two months, January and July 1931.

METHOD OF MAKING THE GRAPHS

The graphs are best made on a sheet of close-lined exercise paper, one that has thirty or more lines to the page; each space can then be used for one day. For temperature lines are drawn across at every ½ inch and numbered for every 4°. Rainfall columns are drawn their actual height. The strip from the left side of a graph (Fig. 126) may be taken as a pattern.

Draw the following combined rainfall and temperature graphs for 1931. Write a note on each graph, commenting where possible on its contrasts with other graphs:

D. 13. Greenwich, January.
D. 14. Greenwich, July.
D. 15. Bombay, January.
D. 16. Bombay, July.
D. 17. St. Lucia (W. Indies), January.
D. 18. St. Lucia (W. Indies), July.
D. 19. Wellington (N.Z.), January.
D. 20. Wellington (N.Z.), July.

D. 21. Grenada (W. Indies), January.
D. 22. Grenada (W. Indies), July.
Draw the temperature graphs (1931) of :
D. 23. Vladivostock, January and July.
D. 24. Nanking, January and July.
D. 25. Shanghai, January and July.
D. 26. Draw the January and July temperatures (max. and min.) for Winnipeg on the same graph.
D. 27. Draw the January and July temperature (max. and min.) for Vancouver on the same graph and write a note comparing them with those for Winnipeg.

QUESTIONS ON PART THREE

A. 1. Given a maximum and a minimum thermometer, when would you make the observations, how would you record them, and what use would you make of them ?
A. 2. What observations are made regarding winds ?
B. 1. What is the characteristic course of the winds that blow in our part of the world ?
B. 2. When does the wind "back" ?
B. 3. Describe the rain-gauge and the method of using it.
C. 1. For what is the barometer used ? How did it get its name of "weather-glass" ?
C. 2. Make a list of the various distributions found on the Daily Weather Report and by the side of each show how it is represented.
C. 3. What are sea-level isotherms ? Explain how they are drawn.
C. 4. How does the "Swing of the Rainbelt" affect the climate of (*a*) Equatorial stations, (*b*) stations in the Sudan, (*c*) those along the southern shores of the Mediterranean ?
C. 5. Draw a diagram to show, broadly, the wind-belts over the Pacific.
C. 6. Compare and contrast the monsoons with land and sea breezes.
D. 1. Write a note on (*a*) aneroid, (*b*) millibar, (*c*) isobar.
D. 2. Draw a diagram of a depression and the winds associated with it (*a*) over Britain, (*b*) over Australia.

PART IV

THE MAP

Chapter Twelve

DISTRIBUTION MAPS AND DIAGRAMS

MAKING A POPULATION MAP FOR WALES

POPULATION maps of the kind that are found in atlases would take far too long to construct in school because they are founded on maps divided into hundreds of small areas, e.g. parishes. In place of these numerous divisions we shall here consider only the twelve counties.

The first three columns in the table give the name of each county, its area in square miles, and its population.

County.	Square Miles.	Population.	Persons per sq. Mile.	
Anglesey . .	276	49,000	174	B
Brecknock . .	733	58,000	78	A
Cardigan . . .	692	55,000	79	A
Carmarthen . .	920	179,000	195	B
Carnarvon . .	572	120,000	210	B
Denbigh . . .	666	157,000	236	B
Flint . . .	264	112,000	439	C
Glamorgan . .	813	1,226,000	1,557	D
Merioneth . .	660	43,000	65	A
Montgomery . .	797	48,000	60	A
Pembroke . .	614	87,000	141	B
Radnor . . .	458	21,000	46	A

The method of constructing the map is as follows:

1. Divide the number of people by the number of square

miles to find the number of persons per square mile in each county (fourth column).

2. Arrange these numbers in order of size, beginning with the smallest.

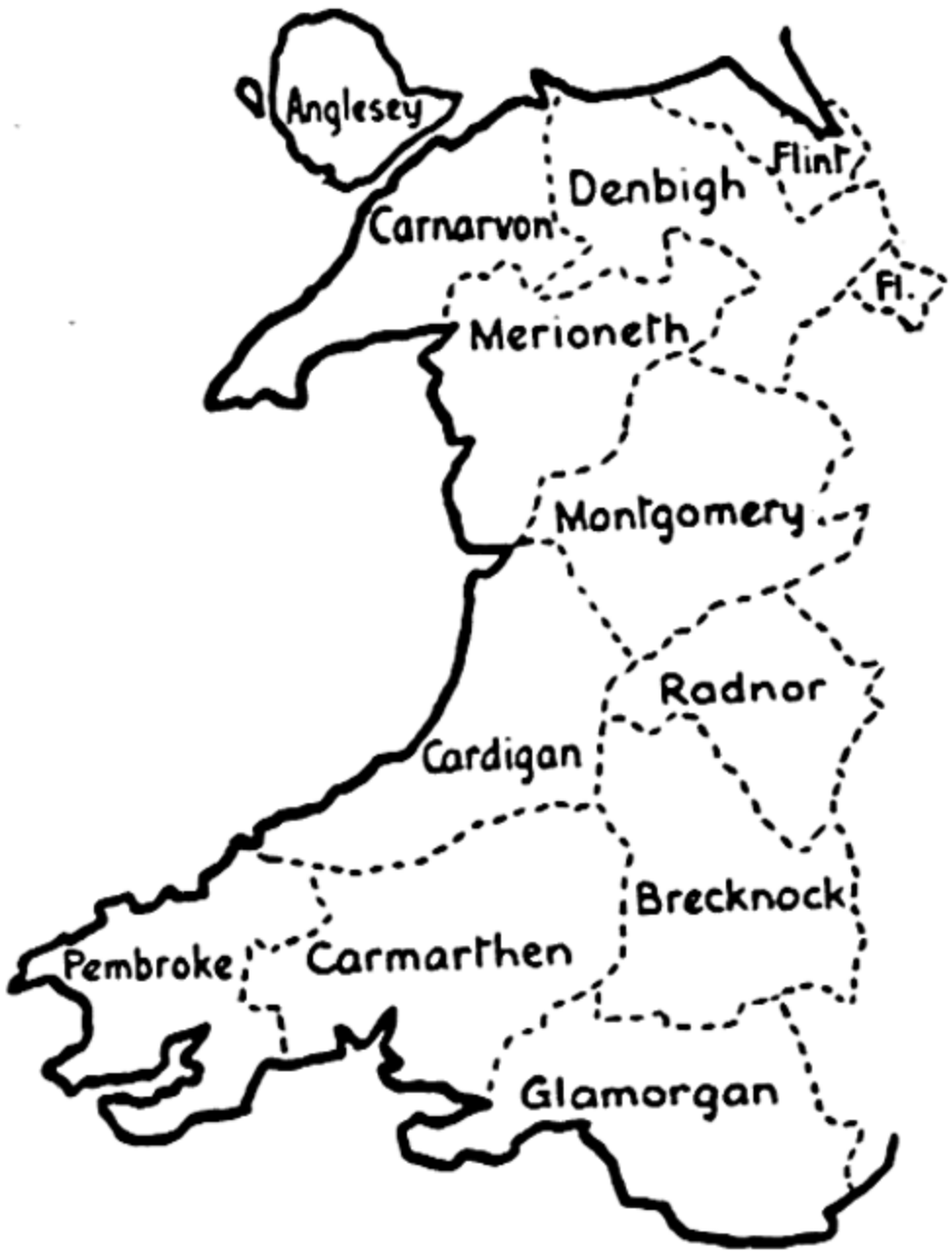


FIG. 127.—WALES.

3. Divide them into four groups ABCD by lines drawn at 100, 300, 900.

4. In the last column put the letter for each county.

5. Shade the map thus: B very lightly, D very heavily, C intermediate, A leave white.

C. 1. Make a tracing of the county map of Wales and follow out instructions 2, 3, 4, 5 above.

The dividing line between the groups should fall, if possible, where there are big gaps in the numbers. They should also be at such intervals as 100, 200, 300; 50, 100, 150; 64, 128, 256, 512.[1]

C. 2. Draw a "sheep" map of Wales, using the same method as for the population map.

C. 3. Draw a "cattle" map of Wales.

ANOTHER POPULATION MAP



FIG. 128.—CARNARVON POPULATION.

Fig. 128 illustrates another method of drawing a population map. Here one dot represents 10,000 people, and as there are 130,975 people in the county the number of dots is 13. In placing them the very mountainous areas have been avoided.

[1] In Book III of the *Columbus Geographies*, Senior Series, there is a population map of Wales made with these intervals. Compare this with your own map.

C. 4. Make a copy of the county map of Wales. In each county put one dot for each ten thousand people. (Re-write the population table, omitting the last four figures in each number—e.g. for Anglesey write 5 in place of 49,000.)
C. 5. Make a sheep map of Wales by the dot method.
C. 6. Make a cattle map of Wales by the same method.

MAPS OF SCOTLAND

For these exercises see figures on page 195.

Make the following maps:

C. 7. Population map shaded according to the density of population in each county like the one made for Wales.
C. 8. Population map, one dot for each ten thousand persons.
C. 9. Sheep map, one dot for each ten thousand sheep.
C. 10. Wheat map, one dot for each 4,000 acres of wheatland.

THE COUNTIES OF ENGLAND IN DIAGRAM

In this group of exercises a square inch represents a thousand square miles and a dot ten thousand people.

EXAMPLE

Draw diagrams to compare the population of Westmorland with that of Devon.

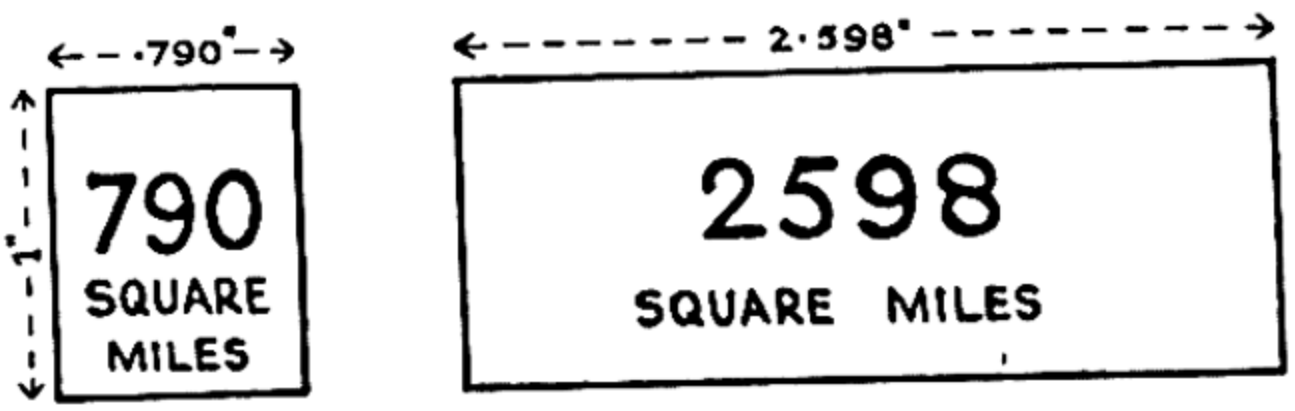


FIG. 129.—AREAS OF WESTMORLAND AND DEVON.

Area of Westmorland 790 square miles, ·790 square inches.

Area of Devon 2,598 square miles, 2·598 square inches.

Population of Westmorland 65,000; number of dots 8·1234 or 8.

Population of Devon 732,000; number of dots 73·2 or 73.

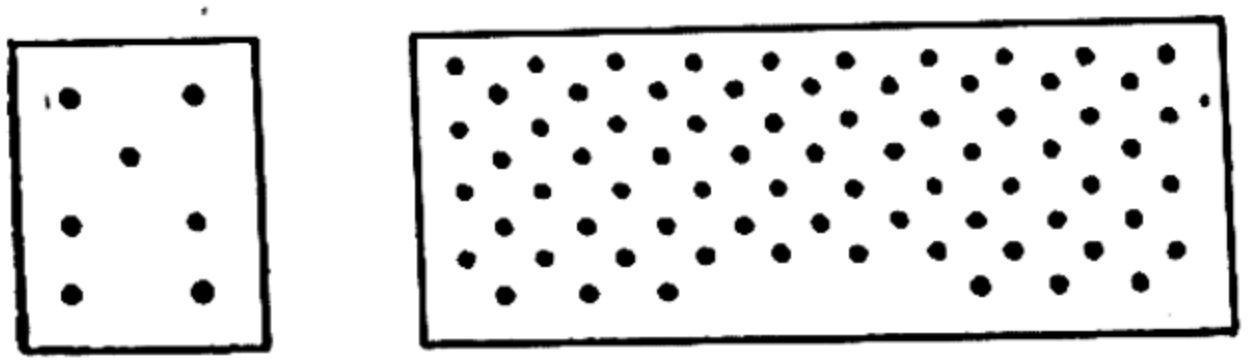


FIG. 130.—AREAS AND POPULATIONS OF WESTMORLAND AND DEVON.

The final diagrams are put side by side here, but it is sometimes better to put them one above the other.

C. 11. Draw the diagrams comparing the population of Westmorland with that of Devon.

C. 12. Draw similar diagrams for the following pairs of counties:
(*a*) Norfolk and Worcester.
(*b*) Rutland and Lincoln.
(*c*) Lancashire and Wiltshire.
(*d*) Huntingdon and Oxford.

SHEEP

Diagrams in the same style as those for population can be drawn for sheep.

C. 13. Draw diagrams to compare the areas and number of sheep in the following pairs of counties.
(*a*) Norfolk and Worcester.
(*b*) Rutland and Lincoln.
(*c*) Lancashire and Wiltshire.
(*d*) Huntingdon and Oxford.
(*e*) Westmorland and Devon.

CATTLE

C. 14. Draw diagrams to compare the areas of the counties and number of cattle in each in:
(*a*) Wiltshire and Worcester.
(*b*) Stafford and Kent.
(*c*) Cheshire and Lancashire.
(*d*) Somerset and Westmorland.

WHEAT

D. 1. On an outline map with the county boundaries marked make a wheat map of England and Wales, putting one dot for each 4,000 acres of wheatland. (Use the physical map in the atlas and remember that wheat is seldom grown above the 600-feet line in this country.)

COUNTRY DIAGRAMS

These can be conveniently drawn on a scale of one square inch for a hundred thousand square miles of area and one dot for ten million people.

EXAMPLE

Draw a diagram to represent the area and population of the U.S.A. in 1930.

Area.

2,973,766 square miles
29·73766 (hundred thousand)
30 squares

Population.

122,775,046
12·2775046 (ten millions)
12 dots

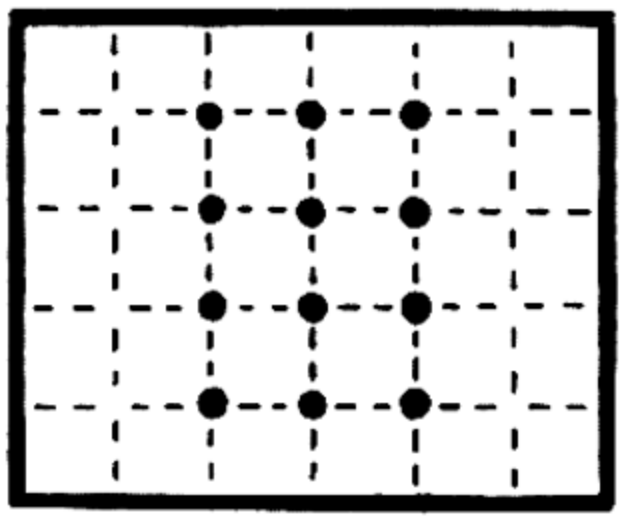


FIG. 131.

C. 15. Draw diagrams on the same scale as the above to represent the comparative areas and populations of:
(*a*) Brazil, Australia, Russia, United States.
(*b*) Germany, Belgium, Gt. Britain, Japan, Kenya.

C. 16. Using a scale of one dot for a million people, draw diagrams for the size and population of Japan, Queensland, California.

D. 2. Draw diagrams to represent the comparative areas and populations of the following countries, distinguishing between whites and negroes (e.g. a blacklead dot for whites and an ink dot for negroes):
(*a*) Natal, Georgia, Newfoundland.
(*b*) New York State, Virginia, Maine, California.

	Area in sq. Miles.	Population.	
		White.	Black.
Natal	35,284	136,838	1,292,560
Newfoundland	42,734	277,285	—
California	158,297	5,596,203	81,048
Georgia	59,265	1,837,381	1,071,125
Maine	29,895	795,185	1,096
New York State	49,204	12,150,293	412,814
Virginia	42,627	1,771,686	650,165

QUESTIONS ON CHAPTER TWELVE

C. 1. Describe two methods of drawing a population map of Wales by counties.

C. 2. Explain how you would draw rectangular diagrams to compare the areas and populations of two counties or two countries.

Chapter Thirteen

ORDNANCE MAPS

ORDNANCE maps are maps of this country made and sold by the Government. The word "Ordnance" generally refers to large cannon, and originally it was the Department that looked after the cannon that surveyed the country and drew the maps. The work was begun in 1791, and though in 1889 it was transferred to the Board of Agriculture and Fisheries, the old name is still used.

SEA-LEVEL

Heights on ordnance maps were formerly reckoned from the average level of the sea at Liverpool. Now the average level of the sea at Newlyn in Cornwall is used. This is the "Datum Line," and is marked O on the maps.

SYMBOLS USED ON ORDNANCE MAPS

So many symbols are used on Ordnance maps that only a small portion of them can be dealt with in one short chapter. The meaning of most of those that we shall come across in the maps that follow can be understood with very little explanation.

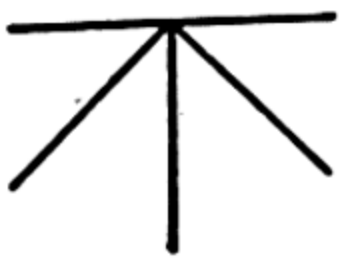


FIG. 132.—A BENCH-MARK.

Bench-Marks.—When the height of a place above sea-level has been found by the surveyors, a record is sometimes made on the wall of a building by cutting a horizontal line called a "bench-mark" and marking it with a broad arrow.

THE TWENTY-FIVE-INCH MAP

(I. ALCONBURY. II. LONDON.)

This map is drawn to a scale of 1 : 2,500 or 25·344 inches to a mile, so that to call it the Twenty-five-Inch Map is not strictly accurate.

An inch on the map represents 208·3 feet. In measuring with a ruler we can call this 210 feet ; one-tenth of an inch is then 21 feet.

Everything is drawn strictly to scale on this map.

I. ALCONBURY

Turn to the next two pages, look at the map and picture together, and find all the things mentioned under the picture. Then notice these further points. In Sharp's Lane is a cross with 55 against it. The road at that point is 55 feet above sea-level. Such marks are called Surface Levels or Spot Heights.

The field bordered by the lane is number 158. Its area is 2·887 acres.

On the farther side of the field is a pond. This we can recognize by the fact that the northern and western lines are slightly thickened to indicate water. The curly line, or brace, shows that the area of the pond is reckoned in with field 158.

There are several pumps (P.) and wells (W.) and a sign-post or guide-post (G.P.).

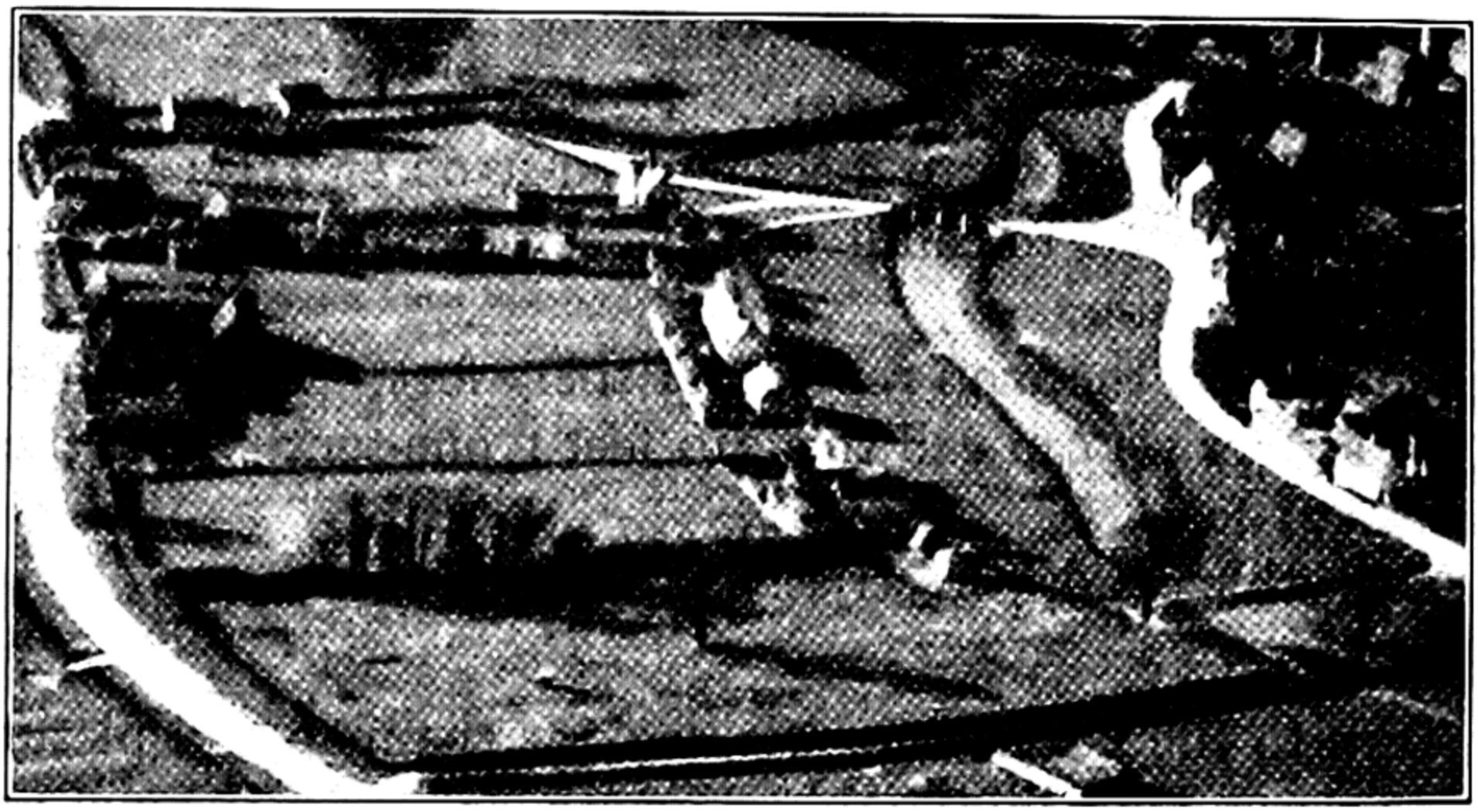
Find first on the picture, then on the map, roads that are fenced on one or both sides and those that are unfenced. How is the difference shown ?

A. 1. Make a copy from the map of :

(*a*) The orchard (167).
(*b*) Field 165 with the well and footpath.
(*c*) Field 158 with the pond and Sharp's Lane.
(*d*) The Green, with the river, bridges, and ford.

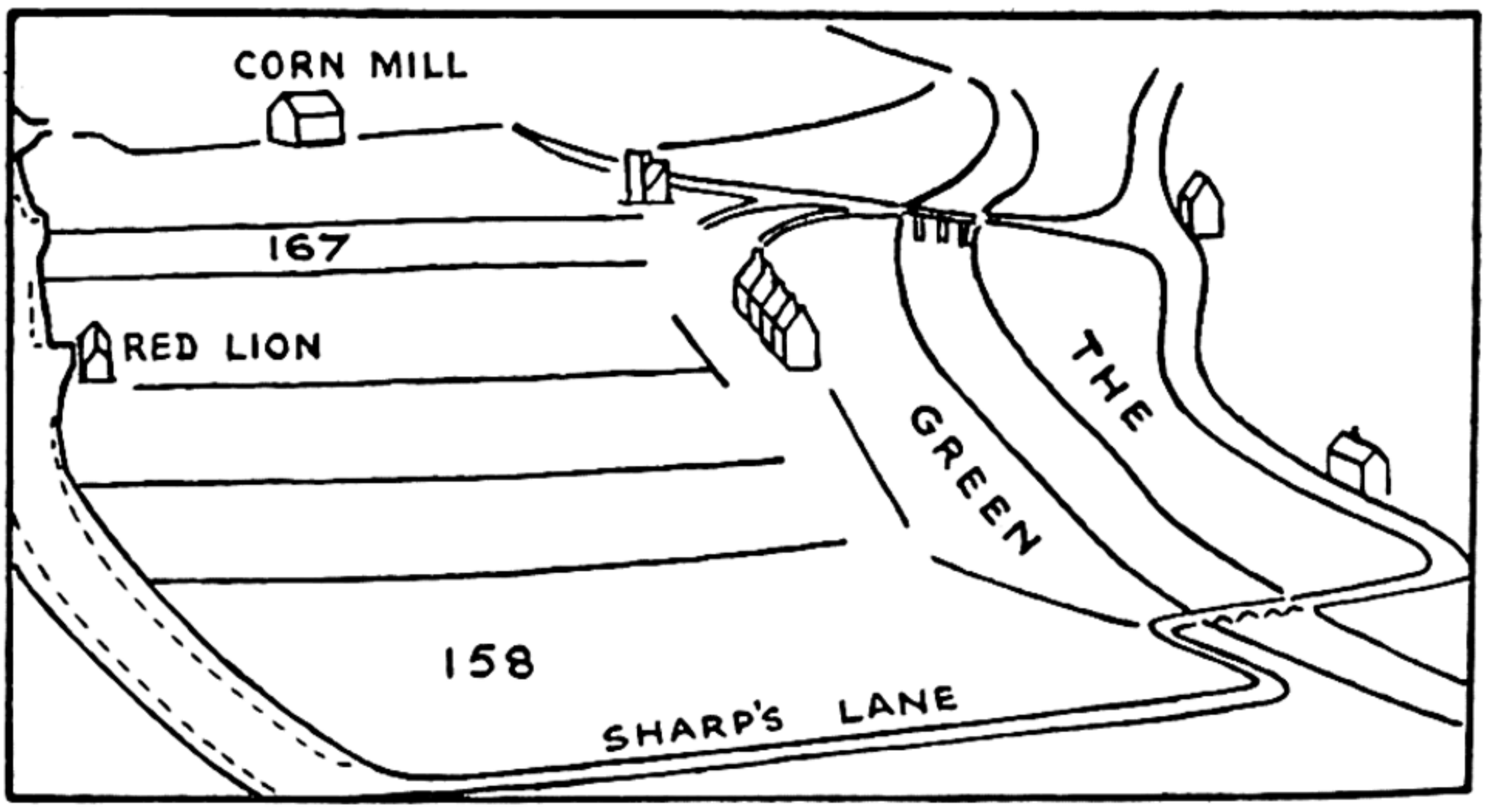
A. 2. Measure the following, using a ruler marked in tenths of an inch. (Let an inch represent 210 feet.)

(*a*) The length of the bridge ; (*b*) the width of the river at the ford ; (*c*) the width of the main road ; (*d*) the length of Sharp's Lane ; (*e*) the length and breadth of the orchard (167), and (*f*) of field 158 ; (*g*) the distance between the bridges.



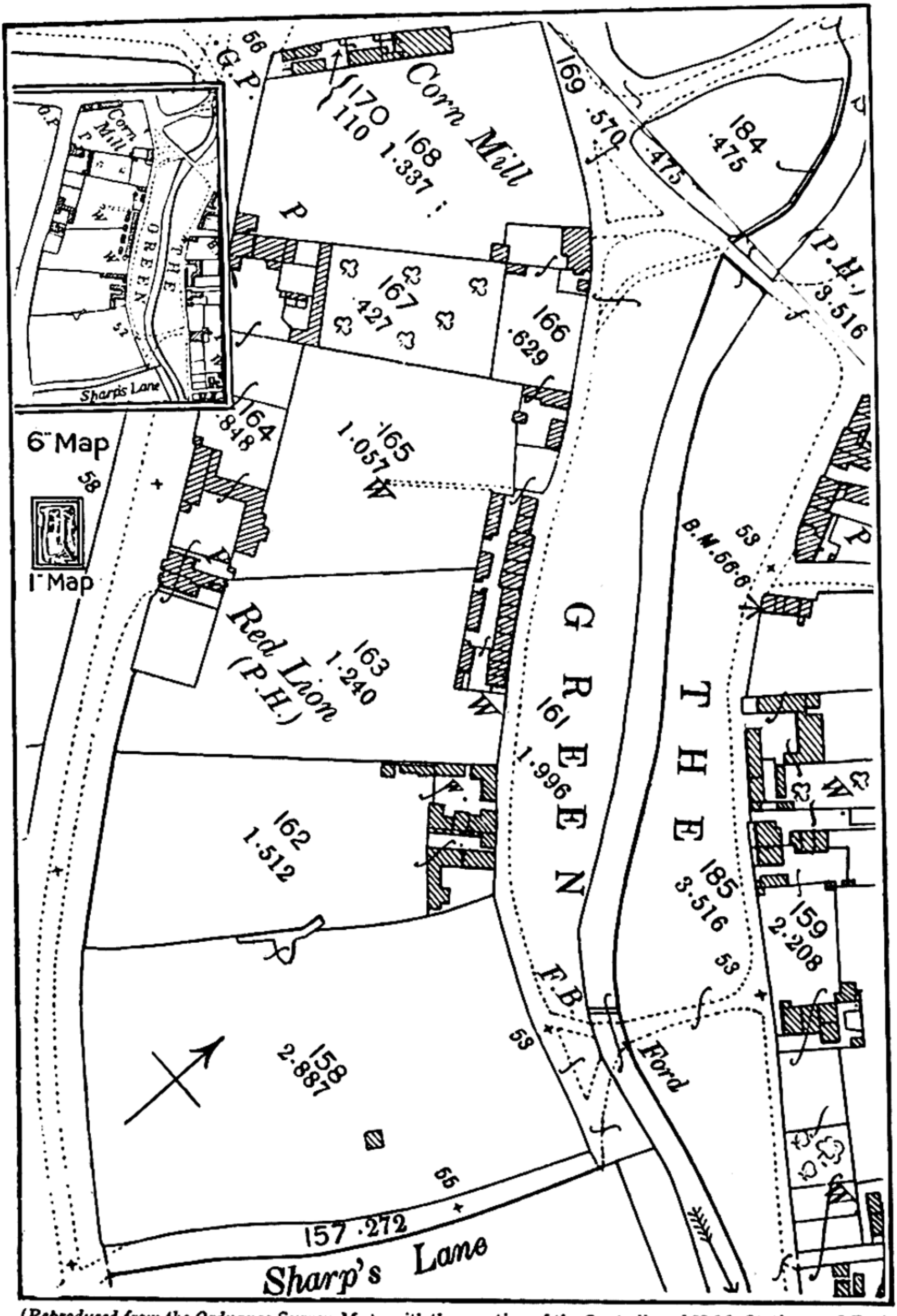
[*Photo by Aerofilms.*

FIG. 133.—ALCONBURY, HUNTS, THE GREAT NORTH ROAD AND THE RIVER.



KEY TO THE PICTURE.

Use the key to find the following in the picture: Sharp's Lane, Field 158, the Corn Mill, Field 167 (orchard), the River flowing through "The Green," the Bridges and Roads (the wide road on the left is the Great North Road), sidewalks for pedestrians. Find the same things on the map with the aid of the picture, and then these: Well and path from houses, other wells and pumps, guide-post, ford, pond, fenced and unfenced roadways, small orchard, enclosure with trees, surface level, bench-mark.



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FIG. 134.—25-INCH MAP (6-INCH AND 1-INCH MAPS INSET).

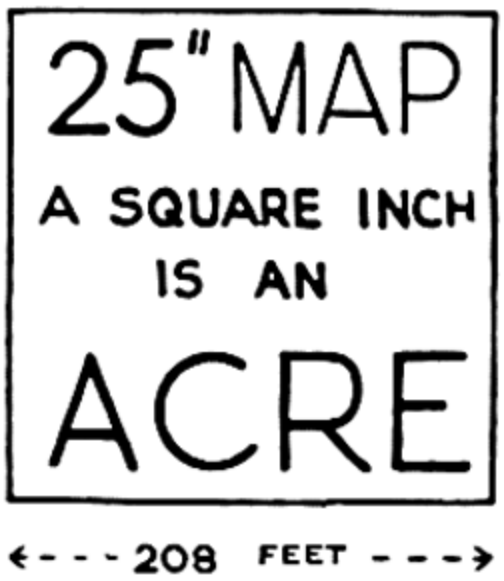


FIG. 135.

AREAS ON THE TWENTY-FIVE-INCH MAP

A square inch on the twenty-five-inch map is for all practical purposes an acre.

B. 1. Mark out a square inch on a piece of tracing-paper, or cut a hole an inch square in a sheet of writing-paper, lay it on the map, and judge the size of the various fields.

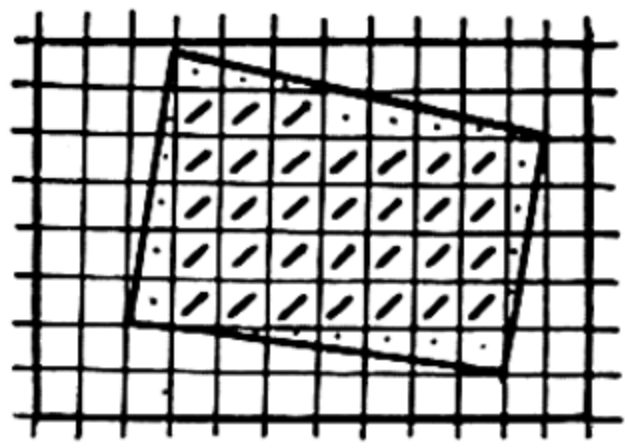


FIG. 136.—FINDING THE AREA OF THE ORCHARD.

Another method. In Fig. 136 the orchard has been traced on to a sheet ruled off in squares of $\frac{1}{10}$ inch. To find its area we count up the whole squares and reckon each portion of a square, whatever its size, as half.

C. 1. Check the areas of 166 and 168 (p. 131) by tracing them on squared paper and counting the squares and parts.

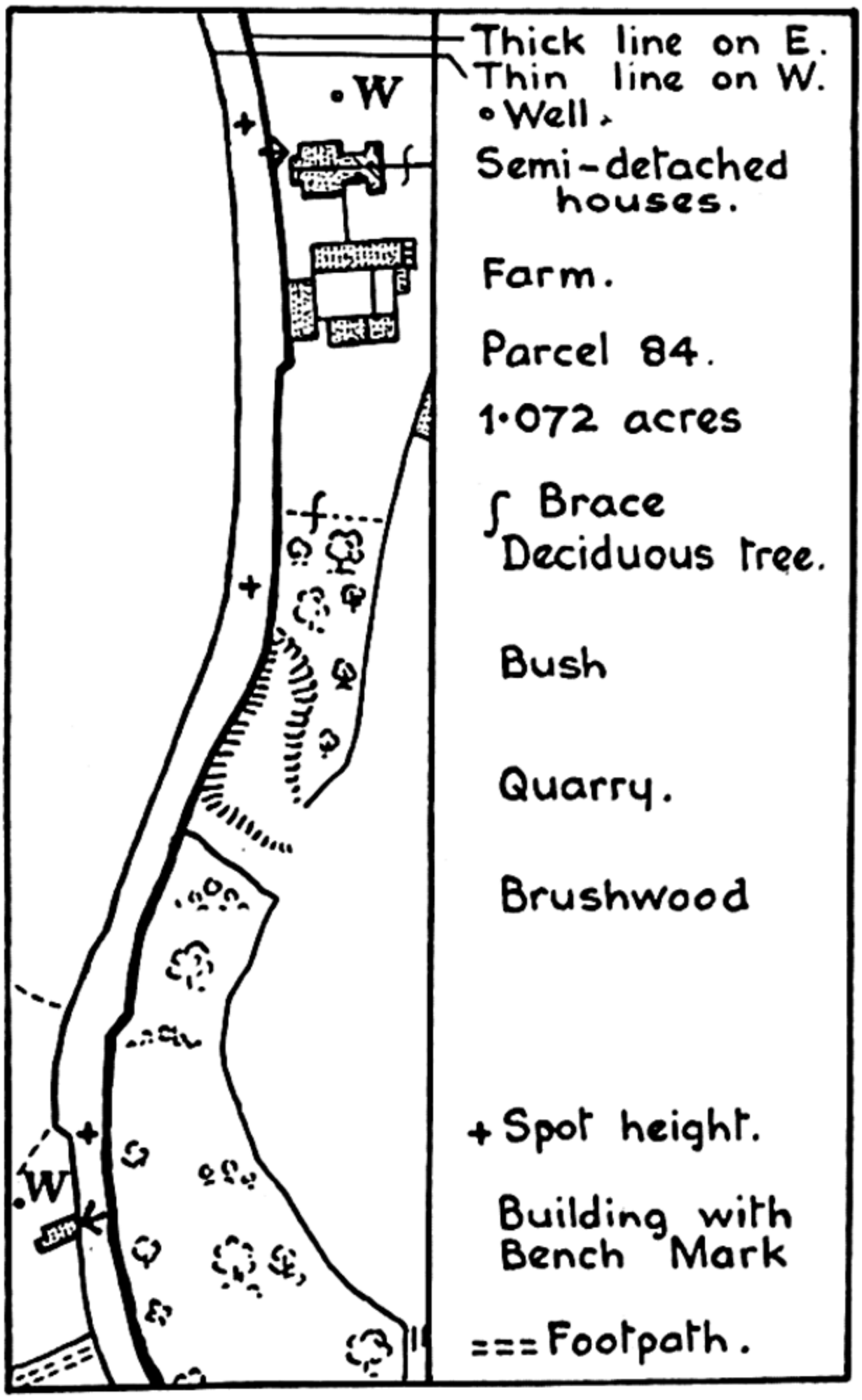
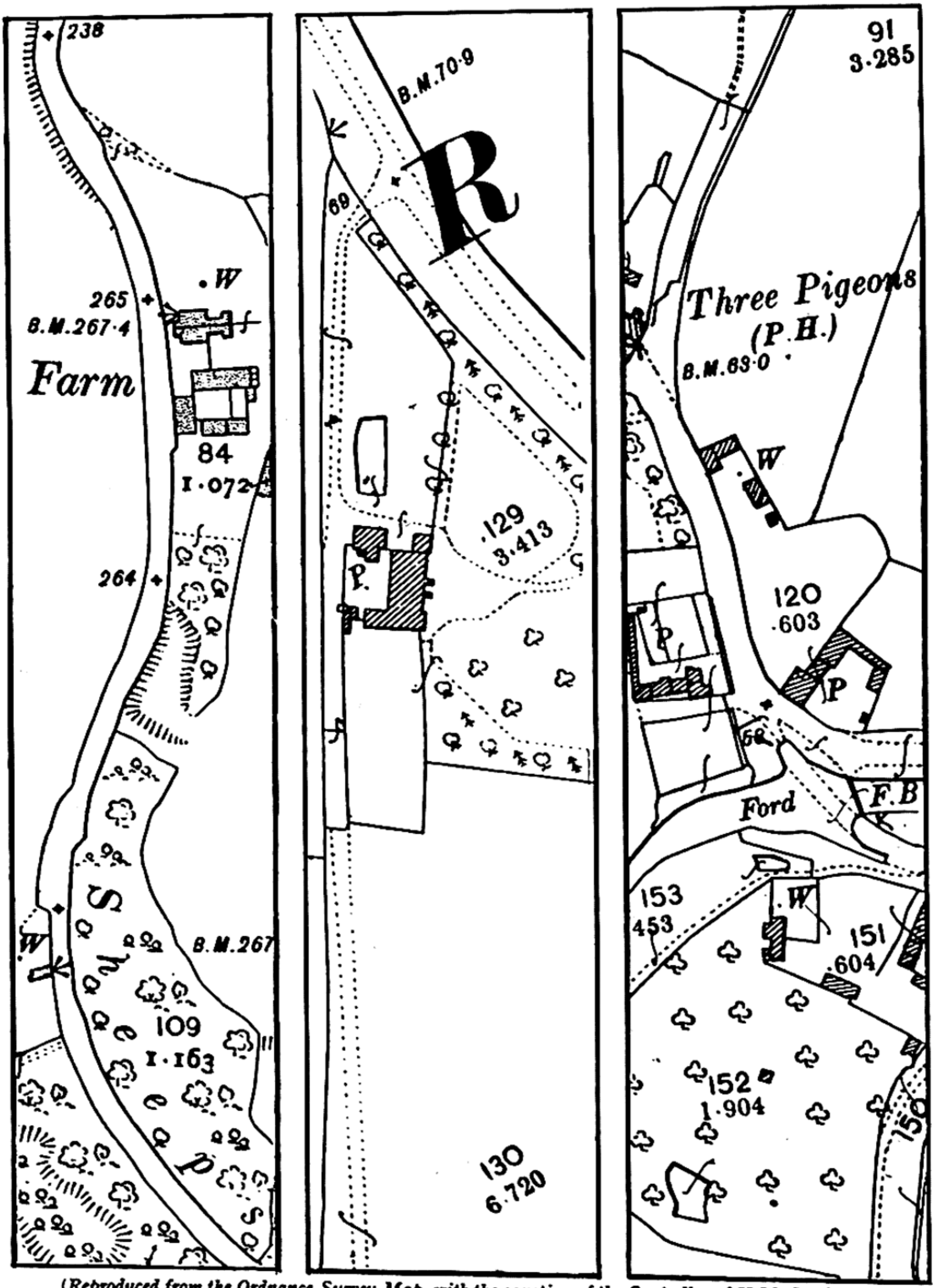


FIG. 137.—SKETCH-MAP AND INDEX (See A, on opposite page).

EXERCISES ON THE TWENTY-FIVE-INCH MAP

Here is a sketch of part of Map A on the next page with an index at the side.

(*Continued on* p. 136.)



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A. B. C.

FIG. 138.



Photo by Aerofilms.

FIG. 139.—LONDON. THE NEIGHBOURHOOD OF CHARING CROSS FROM THE AIR.

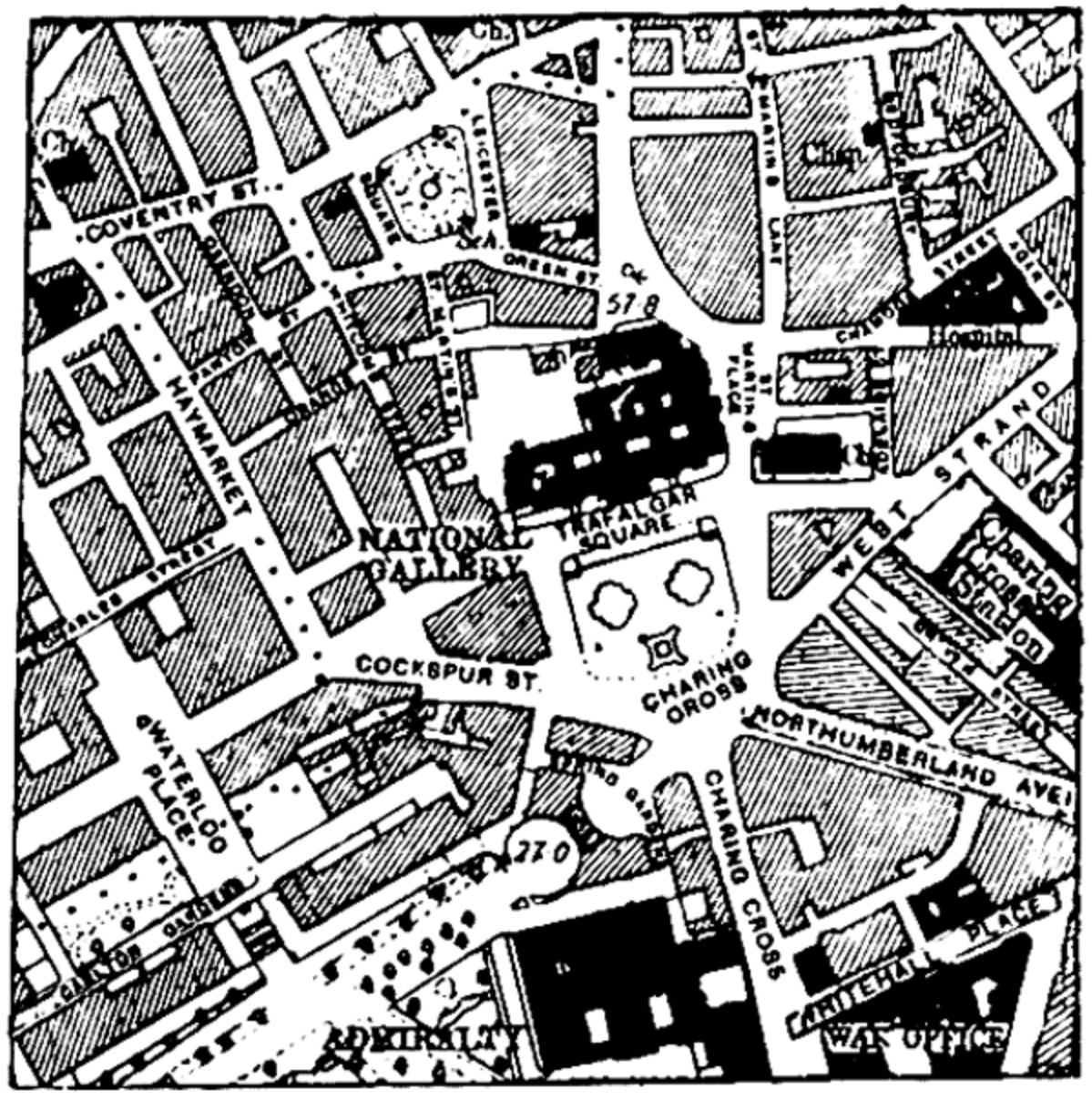


FIG. 140.—THE SIX-INCH MAP.

With the aid of the map find the following in the picture: Charing Cross, Northumberland Avenue, West Strand, Adelaide Street, Charing Cross Hospital, Waterloo Place (notice the Duke of York's Column and the steps leading down from it), Cockspur Street, the Admiralty, St. Martin's Church, National Gallery, Haymarket, St. Martin's St., Oxendon St., Whitcomb St., St. Martin's Lane, Green St., Leicester Square, Chandos St., Charles St., Whitehall Place.

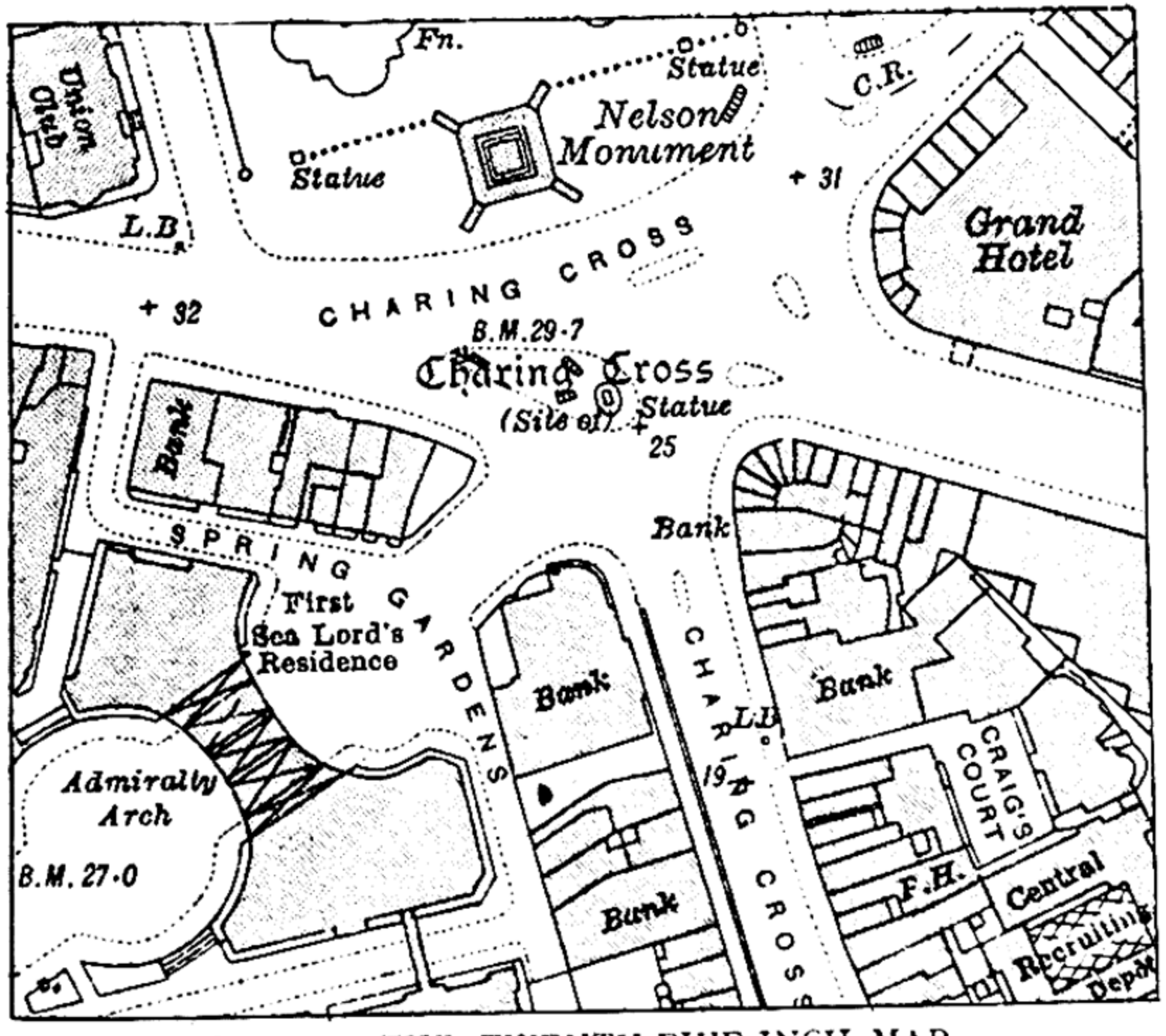


FIG. 141.—THE TWENTY-FIVE-INCH MAP.

Find the following in the map and the picture: The Nelson Monument, the line of posts behind it with the statues at the ends, the basins round the fountains (two), steps leading down to the Underground Railway, the "refuges" in the road, King Charles's Statue (near spot height 25), Admiralty Arch, Grand Hotel, Craig's Court, the First Sea Lord's residence.

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B. 2. Draw a rectangle 2½ inches wide and 6 inches deep and make a sketch of the whole of A with an index.
C. 2. Make a sketch and index for B.
D. 1. Make a sketch and index for C.

II. LONDON (see Fig. 141 on the preceding page).

THE SIX-INCH MAP

I. ALCONBURY

Follow out the instructions under the picture on page 130, finding as many of the features as possible on the six-inch map in the top left corner of page 131.

A. 3. What details on the twenty-five-inch map are omitted on the six-inch ?

II. HATFIELD

On the Six-Inch Map one inch is 880 feet, one-tenth of an inch being 88 feet.

" Every feature of a Six-Inch Map is to scale, save that in crowded towns the width of the streets is sometimes exaggerated to give room for the names, while minor detail of individual houses is necessarily omitted."

Find the following on the two large maps on page 139, and see how far they are shown in the picture:

(1) High Street, Station Road (bottom left corner of picture and map), Thorne Road, Ings Lane, Firthfield Road (running up from the House), Epworth Road, Old Mill Field Road, New Mill Field Road, Back Field Lane.

(2) The church.

(3) The fields in the order in which they are numbered. (Note the footpath in the picture in field 25.)

(4) The fields in the order of their letters (A–J).

In the picture the church tower comes against the vicarage, and there is a path to the right leading to High Street. Find these on the map.

Find the school near the church on the first map, then find it in the picture.

Since the map was drawn a house has been built in the field marked 9 in the key map. Find it in the picture.

Notice that the line of fences under the name Hatfield in the map points to the smithy in Thorne Road. Find the smithy in the picture where it can just be picked out.

In the map there is a vacant plot of ground in the High Street marked 15. Find it in the picture.

Notice the place where the 25-foot contour runs along the side of a road both in the map and the picture. Find two other pieces of contour line.

A. 4. How far along Thorne Road is it from the end of the High Street to the corner of Firth Field Road?

B. 3. Make a list of the roads, and by the side of each write its direction and the length of the part shown on the map.

B. 4. Make rough drawings of fields 13, 8, 10, and 1. Measure the length and breadth of each, and put the figures on your drawings.

C. 3. The crosses for spot heights in the twenty-five-inch map become dots in this one. There are dots also for guide-posts (G.P.). Describe the positions of two spot heights, two guide-posts, and three bench marks. Add a sketch-map.

AREAS ON THE SIX-INCH MAP

When a mile is represented by 6 inches a furlong is $\frac{3}{4}$ inch. A square furlong contains 10 acres, so that if we draw a square with $\frac{3}{4}$-inch sides it will be possible to judge the size of open spaces and fields.

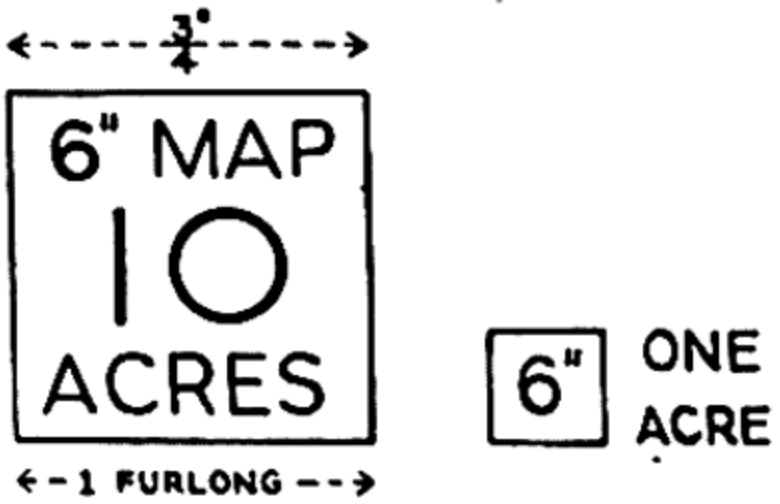


FIG. 142.

B. 5. Cut a square hole with $\frac{3}{4}$-inch sides in a piece of paper. Lay the paper on the map and judge the size of fields 10, 8, and 13.

C. 4. Find the areas of fields 14, 1, 6, and 7.

A square with $\frac{3}{4}$-inch sides has the same area as a rectangle $1 \times \frac{9}{16}$ inch. Draw this rectangle on a piece of tracing-paper and divide it into tenths. Each part will be 1 acre and the areas of the fields can be judged more exactly.

If its shorter sides be bisected and a line drawn through the middle of the rectangle, the figure is divided into twenty half-acres, and the areas can be judged still more exactly.

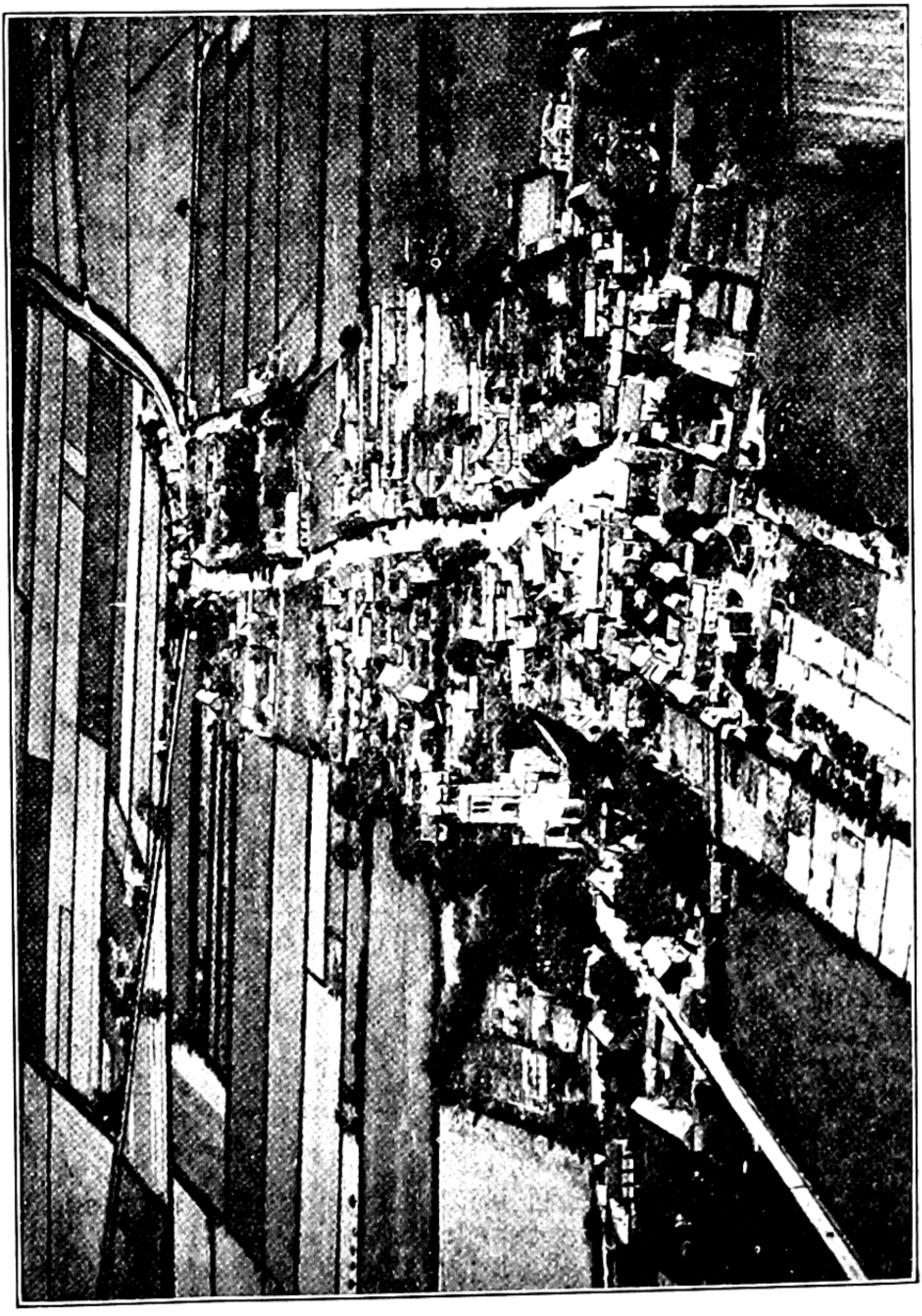
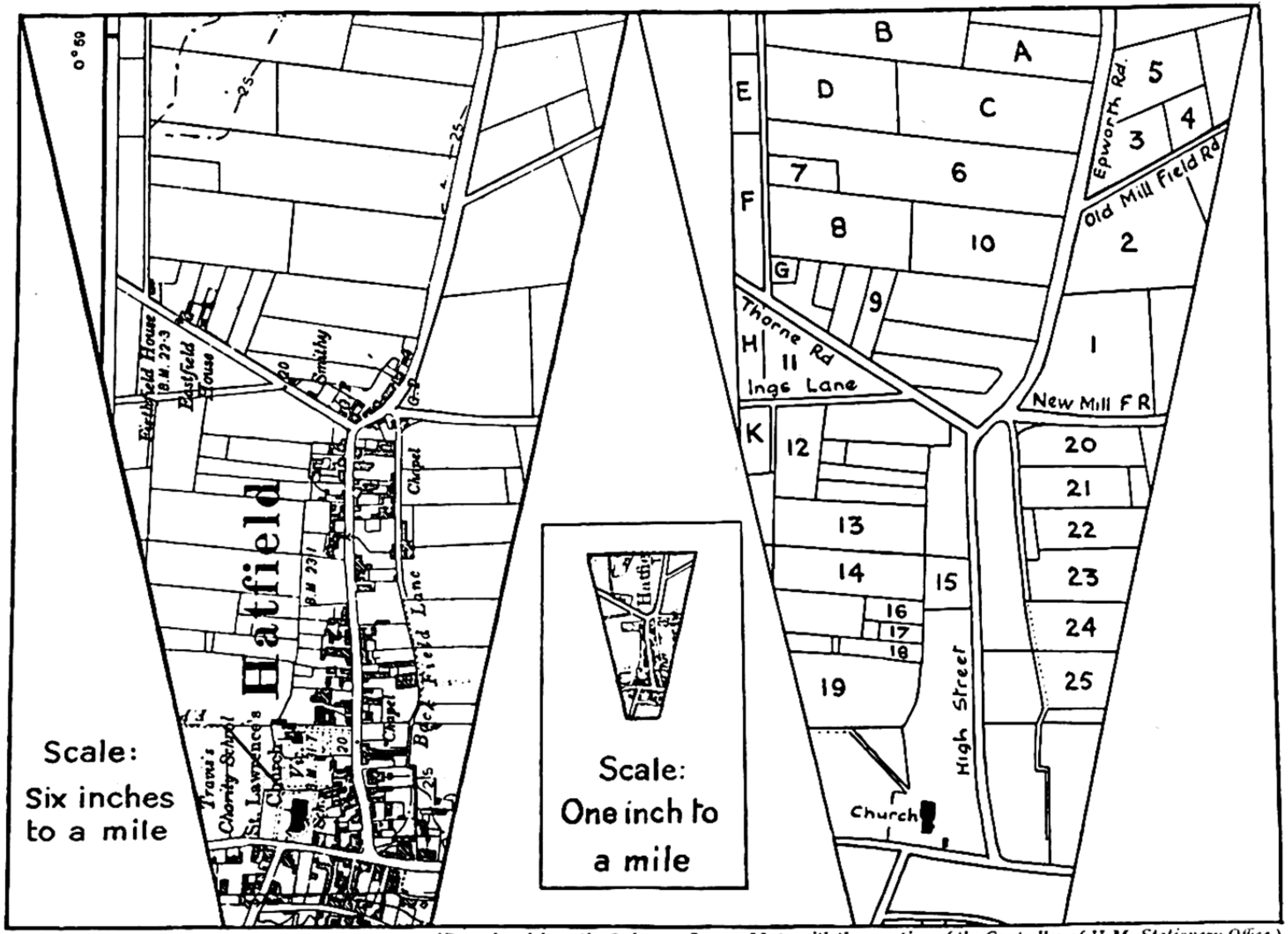
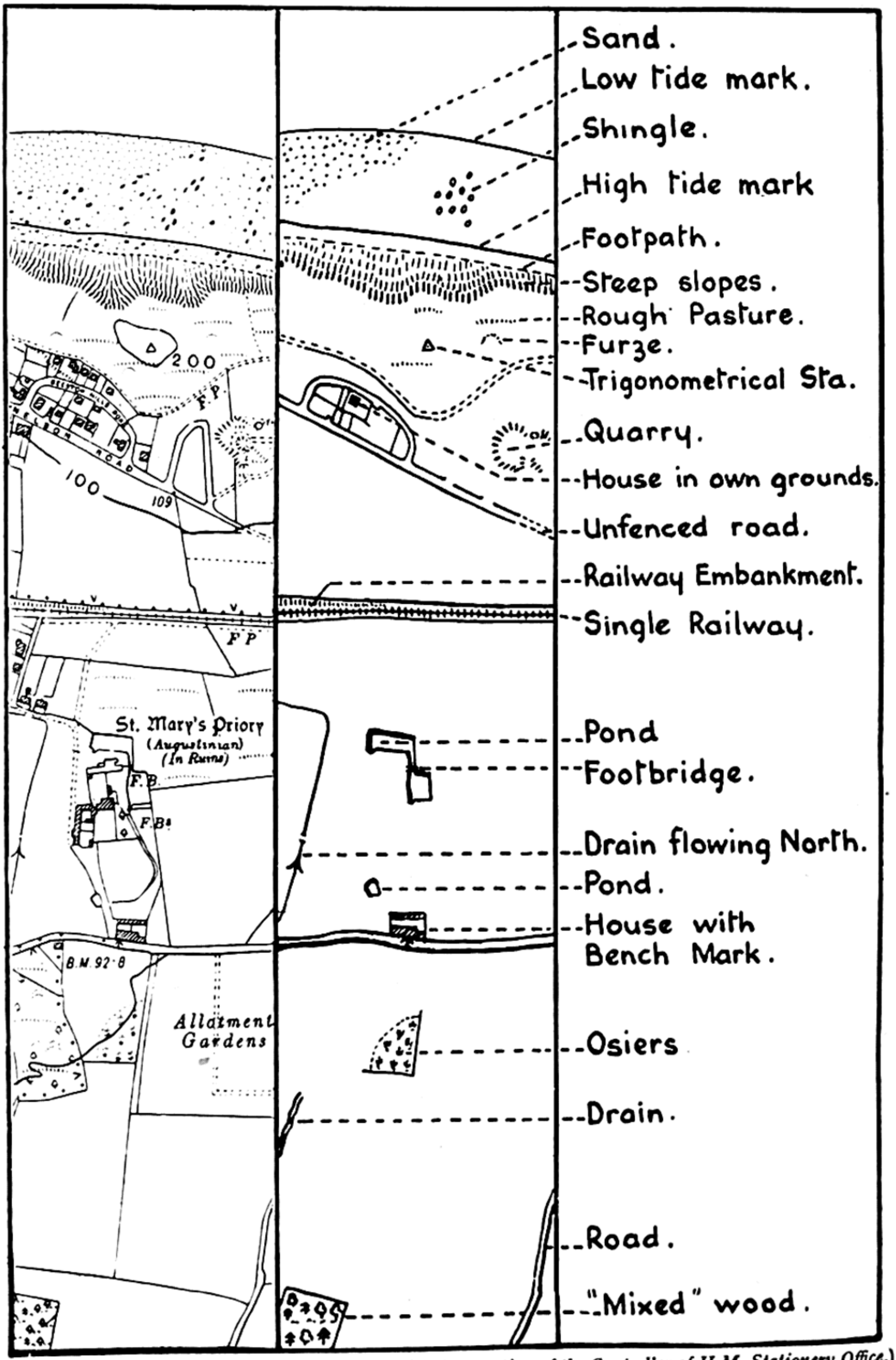


FIG. 143.—HATFIELD, NEAR DONCASTER, YORKS, LOOKING EAST. [*Photo by Aerofilms.*



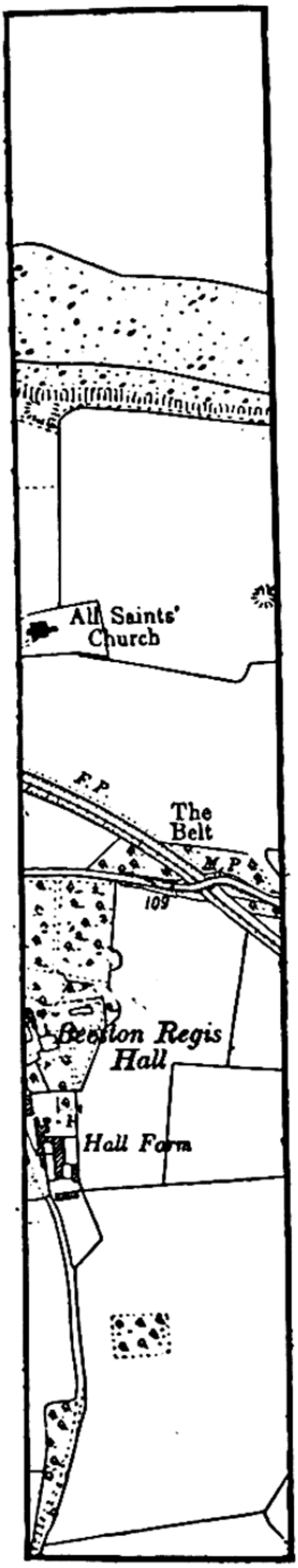
(Reproduced from the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office.)



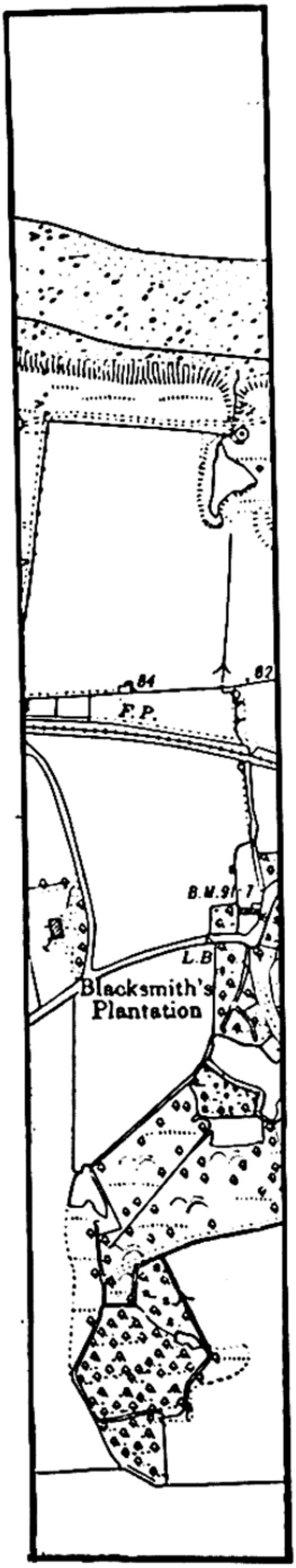
(Reproduced from the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office.)

6-INCH MAP. SKETCH-MAP. INDEX.

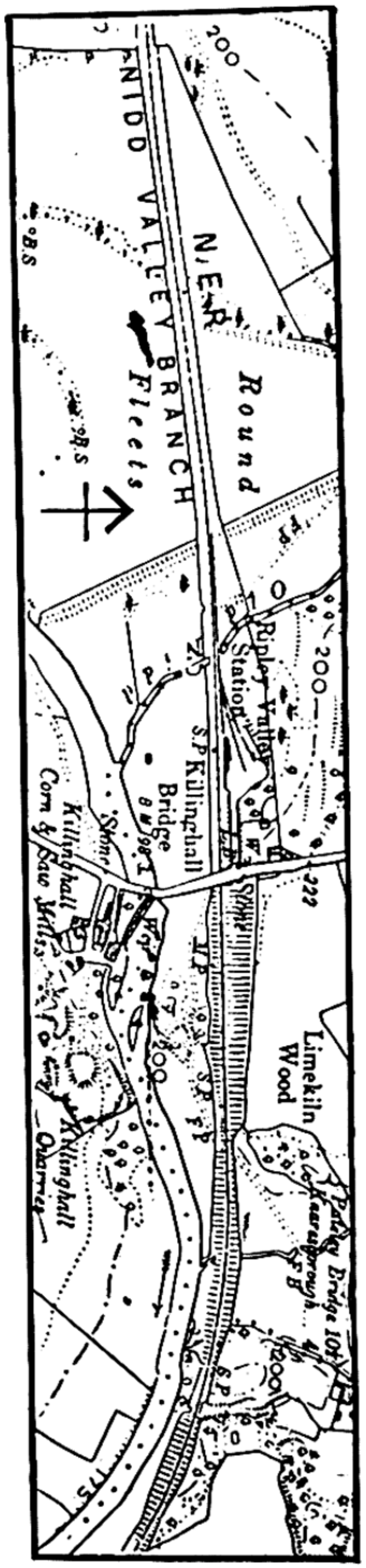
FIG. 145.



I.



II.



III.

(*Reproduced from the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office.*)

FIG. 146.

III. The Six-Inch Map of London

On page 134 is a picture of a portion of London taken from the air and looking northward. In the centre is Trafalgar Square, with Nelson's Column, and there are two fountains playing. The water in the basins around the fountains looks black. The Column is decorated for Trafalgar Day, October 21st, and its shadow nearly touches the National Gallery. In the north-east corner of the Square is St. Martin's Church, from which services are sometimes broadcast on Sunday evenings. The patch of trees at the top of the picture is in Leicester Square. The wide street on the west side of the picture is the Haymarket. In the middle of the east side is part of Charing Cross Station. In St. Martin's Place is the Nurse Cavell Memorial. The school marked on the map has recently been removed. The building just appearing in the bottom right corner is the War Office.

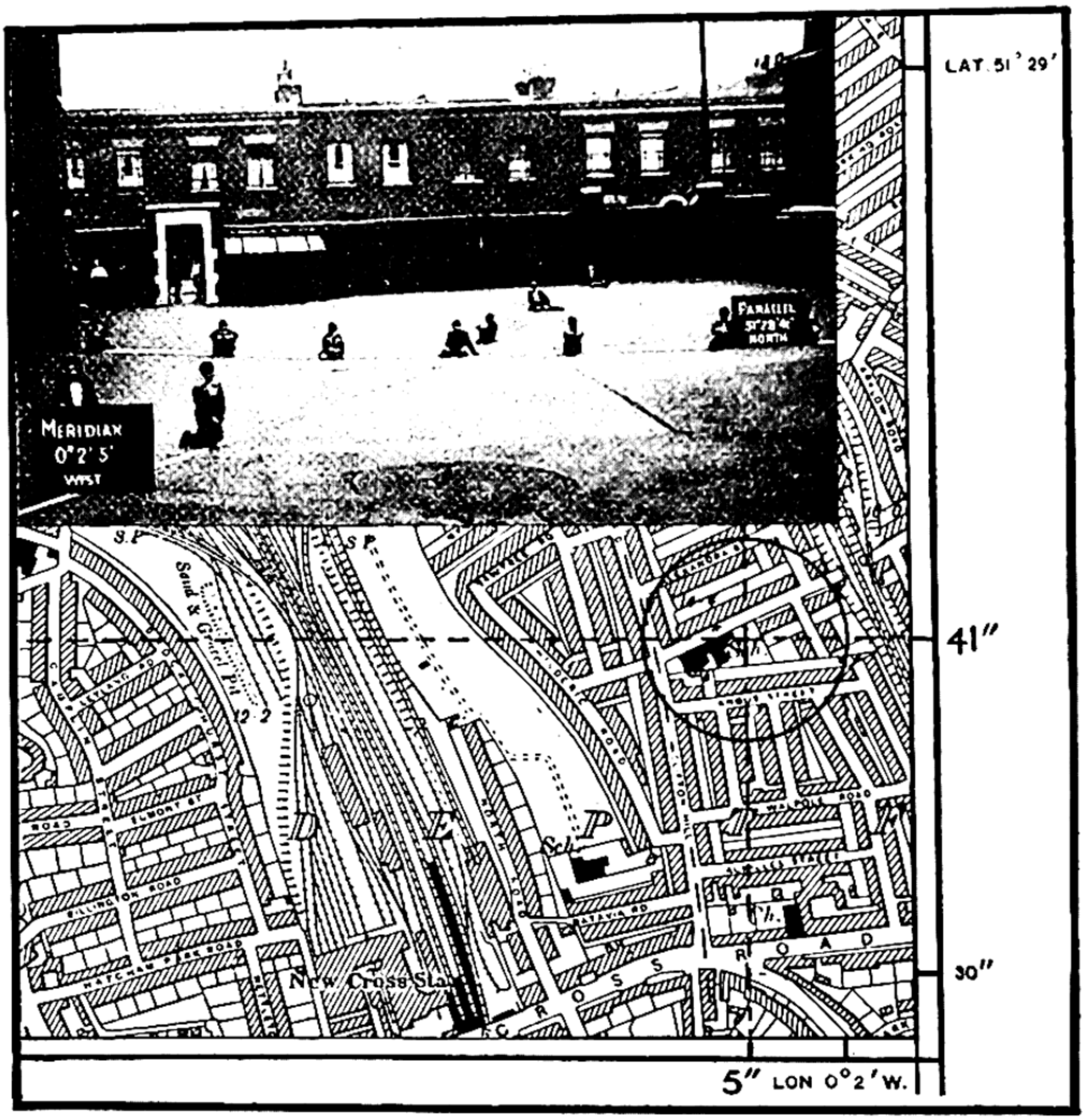
EXERCISES ON THE SIX-INCH MAP

On page 140 is a piece of a six-inch map with a sketch-map at the side of it, and an index.

B. 6. Copy the sketch-map and index.
C. 5. Make a sketch of Map I (page 141) and add an index.
C. 6. Make sketch of Map II (page 141) and add an index.
D. 2. Make a sketch of Map III (page 141) and add an index.

LATITUDE AND LONGITUDE ON THE SIX-INCH MAP

On the margins of the six-inch map longitude is given at every minute, and latitude at every half-minute or thirty seconds. It is therefore possible, by dividing the spaces in the margin, to draw the parallels and meridians a second apart. On the accompanying map it was found that parallel 51° 28′ 41″ north and meridian 0° 2′ 5″ west crossed in a school playgound. In the picture the boys have actually marked them out.



(Reproduced from the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office.)

FIG. 147.—LATITUDE AND LONGITUDE IN THE PLAYGROUND.

The two lines that cross each other in the map are the same as those that cross in the picture.

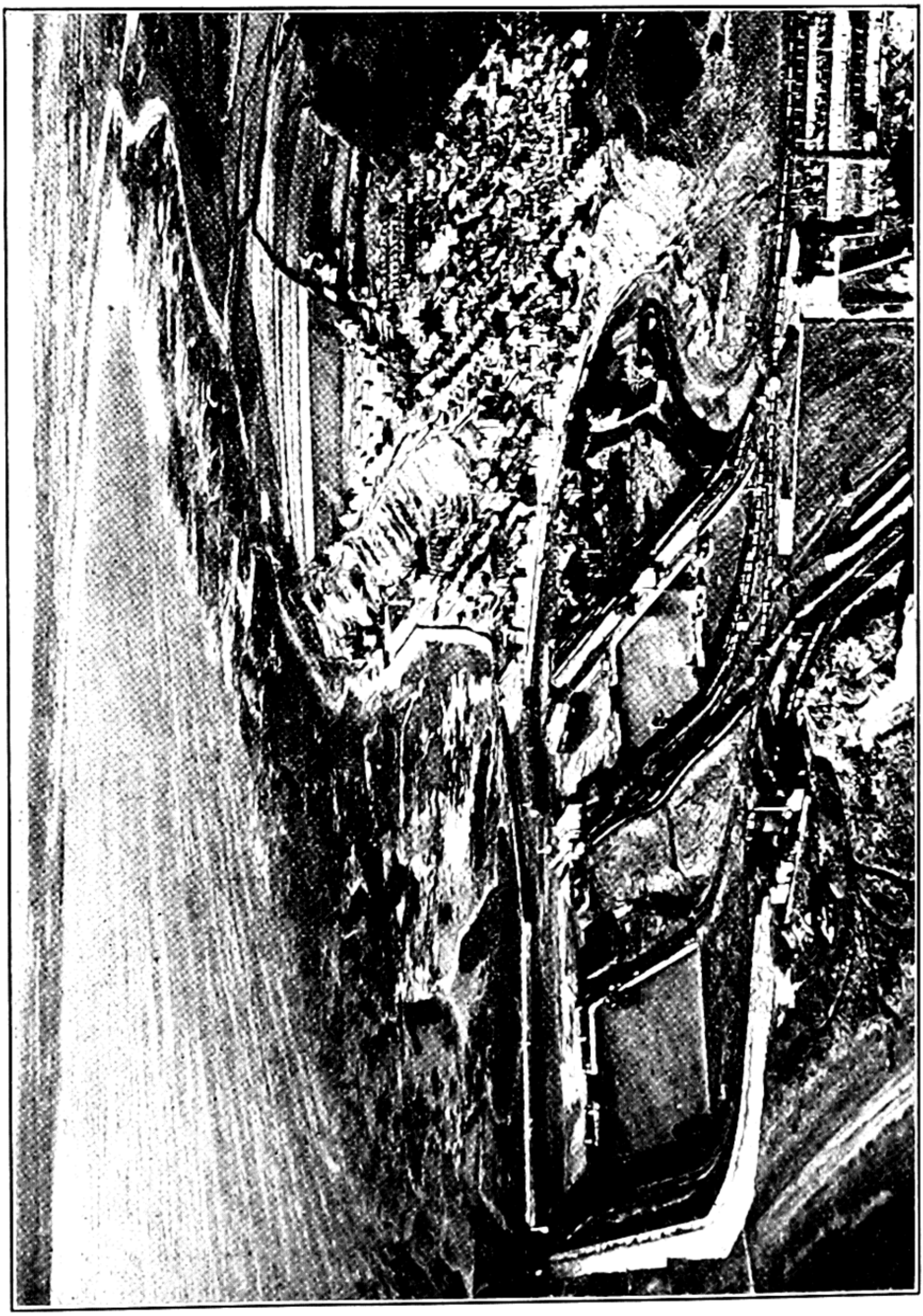
GROUP EXERCISE

Find from the Ordnance Map of your district what lines of latitude and longitude pass through your playground. Mark them out as in the picture and number them.

LATITUDE, LONGITUDE, AND FEET

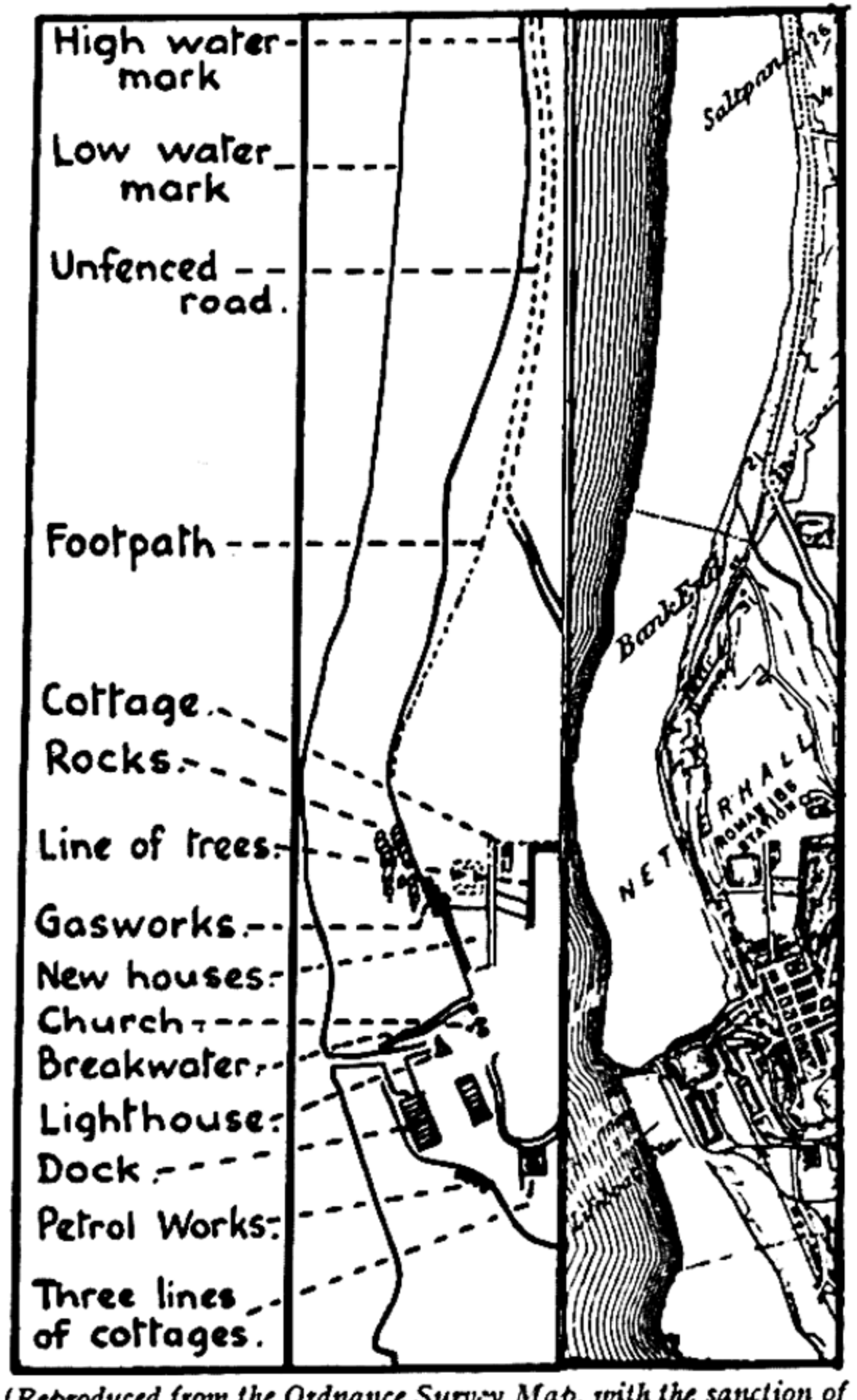
We saw in a previous chapter the relations between latitude, longitude, and miles. With the aid of the six-inch map we can come down to feet.

(Continued on page 146.)



[*Photo by Aerofilms.*

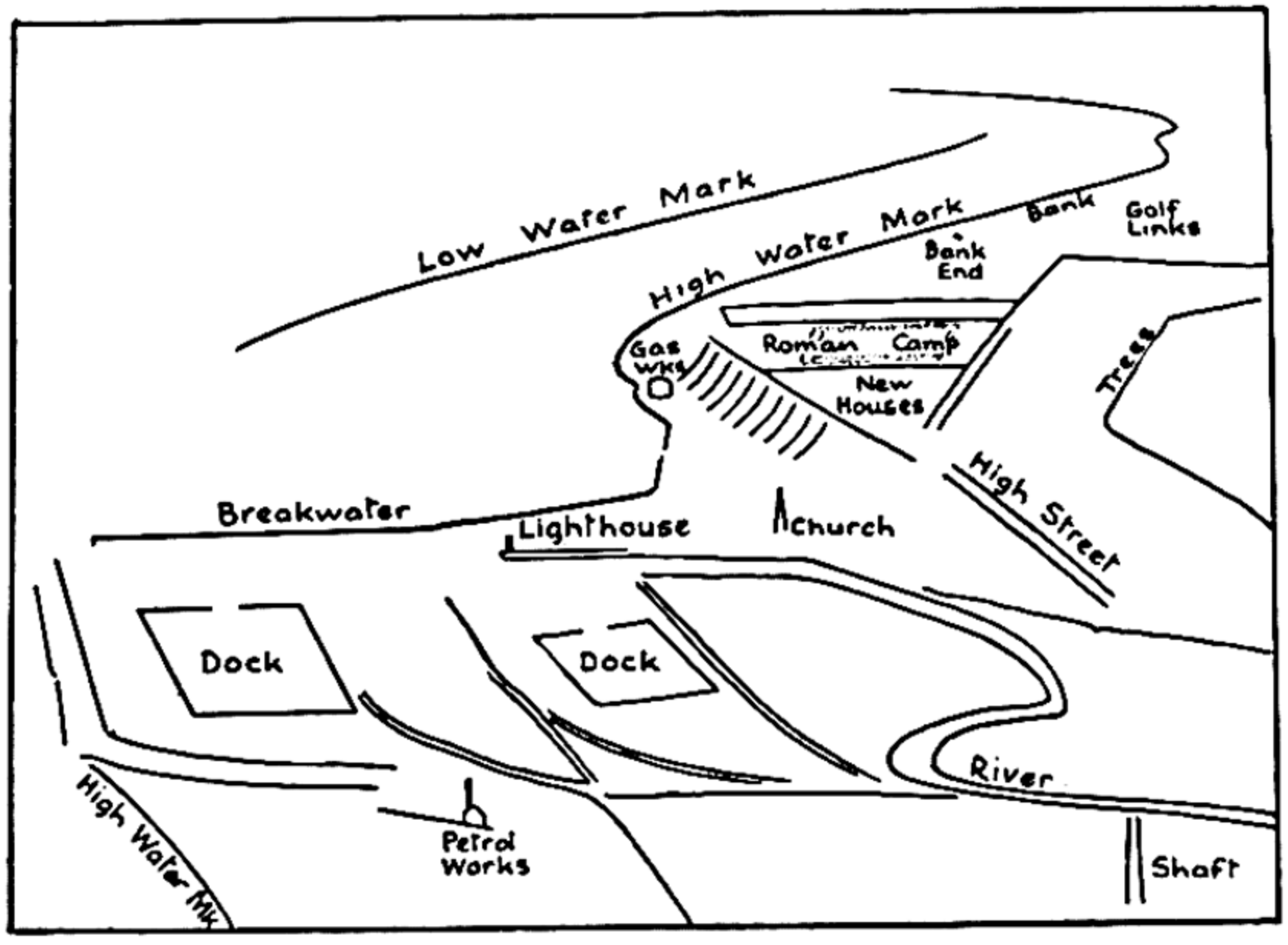
FIG. 148.—MARYPORT, CUMBERLAND, ON THE SOLWAY FIRTH AT THE MOUTH OF THE RIVER ELLEN.



(Reproduced from the Ordnance Survey Map, with the sanction of the Controller of H.M. Stationery Office.)

KEY TO THE MAP. 1-INCH MAP.

FIG. 148A.



KEY TO THE PICTURE.

Use the above key to find the following in the picture: Docks, Low-water Mark, High-water Mark, High Street, New Houses at top of cliff, Houses at bottom of cliff, Gasworks, River, Breakwater, Lighthouses, Railways, Petrol Works, Roman Camp, Golf Links, Bank, Bank End, Shaft and three lines of Cottages, Church, Trees. Find the same things on the map with the aid of its key.

FIG. 148B.

1° of latitude = 69 miles.

1 minute of latitude = 1 nautical mile = 6,080 feet.

1 second of latitude is roughly 100 feet.

In the middle of England the corresponding meridians are 60 feet apart. In some playgrounds, therefore, it is possible to draw two parallels a second apart and two meridians.

Since 1° of latitude is 69 miles, a minute of latitude on a six-inch map is 6·9 inches. Test this along the east side of the map in Fig. 147.

THE ONE-INCH MAP

I. Maryport

On page 144 is a picture of Maryport in Cumberland and the country beyond it. The big curve is the coast of Allonby Bay in the Solway Firth. Below it are maps and a key picture that will be of assistance in understanding them. Notice that the top of the picture goes beyond the limit of the maps.

A. 5. Make a list of things that appear in the picture, but not in the maps.

A. 6. Make a list of things that appear only in the second map and not in the picture.

B. 7. In which direction is the picture taken? In which direction does the shadow of the chimney in the bottom right corner lie? At what time of the day was the photograph taken?

Find in the picture the position of the small triangle that marks the highest point in the neighbourhood 186 feet above sea-level. Imagine the sea rising from its present level to the high-tide mark, then to the 50-ft. mark, then to the 100-ft., then to the 150-ft.

B. 8. When it reached this last height, which houses would still be on dry land?

B. 9. Make a large sketch of the first map, showing the coast, the beach, and the River Ellen. Shade the area occupied by the town. Add a key.

C. 7. Make a sketch, larger than the map, showing the coast, the beach, the rivers, and the contour lines. Shade the land over 100 feet.

II. ALCONBURY

Follow out the instructions under the picture on page 130, finding as many of the features as possible on the one-inch map.

C. 8. What details on the six-inch map are omitted from the one-inch ?

C. 9. Make an enlarged copy of the one-inch map (freehand).

III. HATFIELD

C. 10. Compare the one-inch and six-inch maps, noting especially the gardens and the width of the roads.

C. 11. Make a map in the style of the one-inch, but as large as the six-inch, showing the roads, the church, the school, and the smithy.

QUESTIONS ON CHAPTER THIRTEEN

A. 1. Make sketches to show what symbols are used on Ordnance Maps for steep slopes, conifers, deciduous trees, fruit trees, rough pasture, furze, fenced roads, unfenced roads, footpaths.

A. 2. On which of the scales mentioned in this book are contour lines drawn ; from which are they omitted ?

A. 3. Which map shows every field ? Which gives the areas of the fields ? In which are the fields not marked ?

B. 1. What are Ordnance Maps ? On what scales are they drawn ?

B. 2. From what level are heights measured on Ordnance Maps ? What is this level called ?

B. 3. What is a Bench-mark ? What is a spot height ? How are they shown on the map ?

B. 4. How many feet to an inch are there on : (*a*) the six-inch map ; (*b*) the twenty-five-inch map ?

B. 5. How large is an acre on a 25-inch map ?

C. 1. What is the R.F. of (*a*) the one-inch map ; (*b*) the six-inch ; (*c*) the twenty-five-inch ?

Chapter Fourteen

MAP PROJECTIONS

SINCE the surface of the Earth itself is curved while the map is flat, it follows that we cannot have a map of the earth that is correct in all respects. When, therefore, a new map is to be drawn the first question that has to be answered is : What will it be used for ?

A sailor uses a map that will help him sail from port to port ; a railway engineer requires one that shows him the relief of the land ; and neither can work with the other's map. For the airman new maps have had to be made differing entirely from the sailor's or the engineer's.

Before the outlines of the continents and islands can be drawn on a map, it is necessary to construct the network of parallels and meridians. This network is the " projection." On page 149 are four maps of North America. They were drawn on four different projections or nets because they were wanted for four different purposes, and they are all drawn from the same globe (about three inches in diameter) despite their differing shapes and sizes.

The wrong impression that the map sometimes gives about the globe may be judged from the next illustration, where the same part of the Earth appears in the map and on the globe. The distance along the Equator is the same in both, and the dotted line on the map is the same as the circle round the globe.

THE CRICKET BALL

In this chapter are the instructions for drawing a number of projections, all of them based on a cricket ball on which a

network of meridians and parallels has been marked at intervals of thirty degrees.

The following measurements are approximately correct and

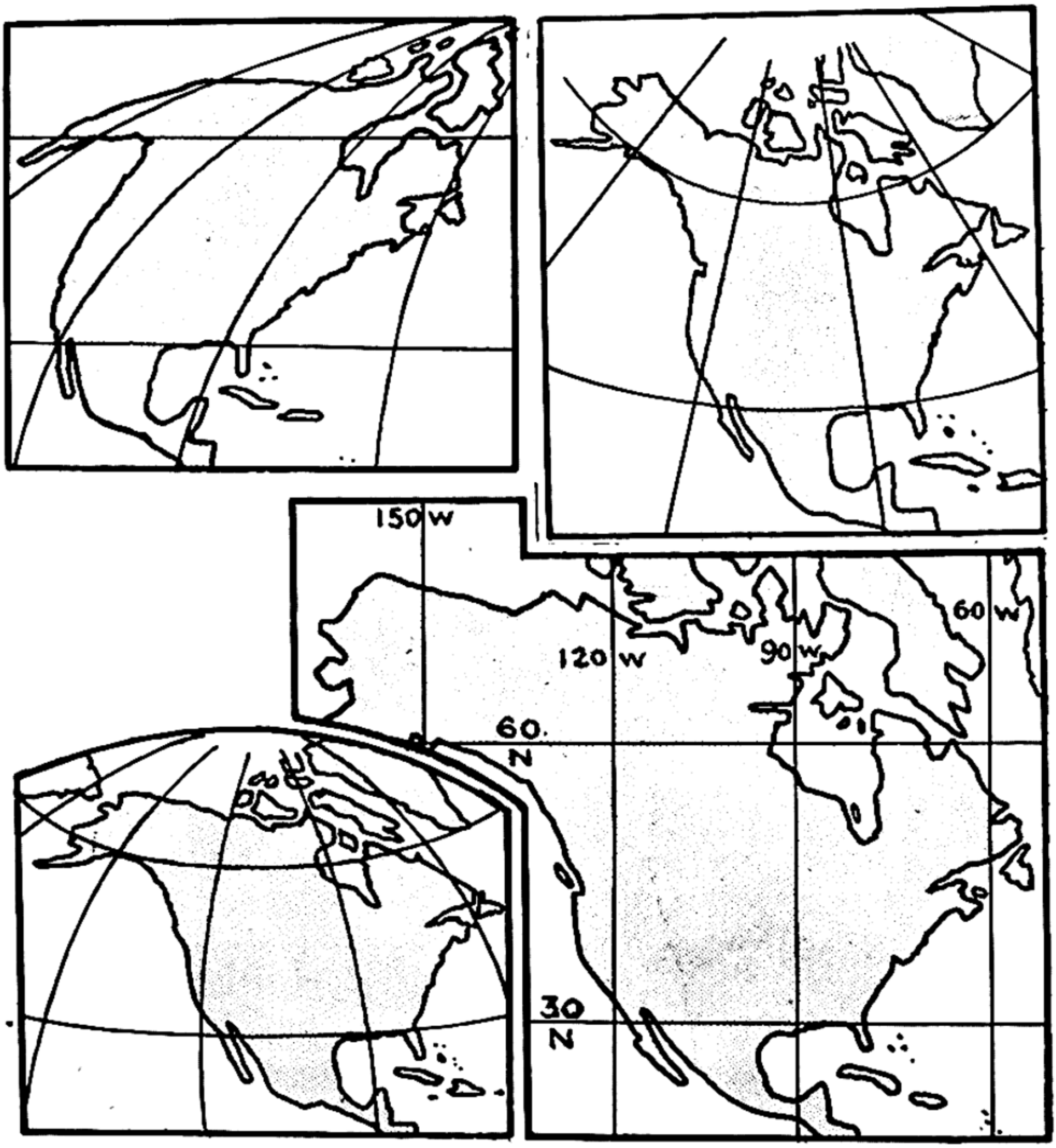


FIG. 149.—FOUR MAPS OF NORTH AMERICA.

They are all made from the same globe, but were drawn for four different purposes.

have the advantage of being easily divided by twelve, so that an ordinary foot-rule used in school (showing eighths and tenths of inches and millimetres) can be used.

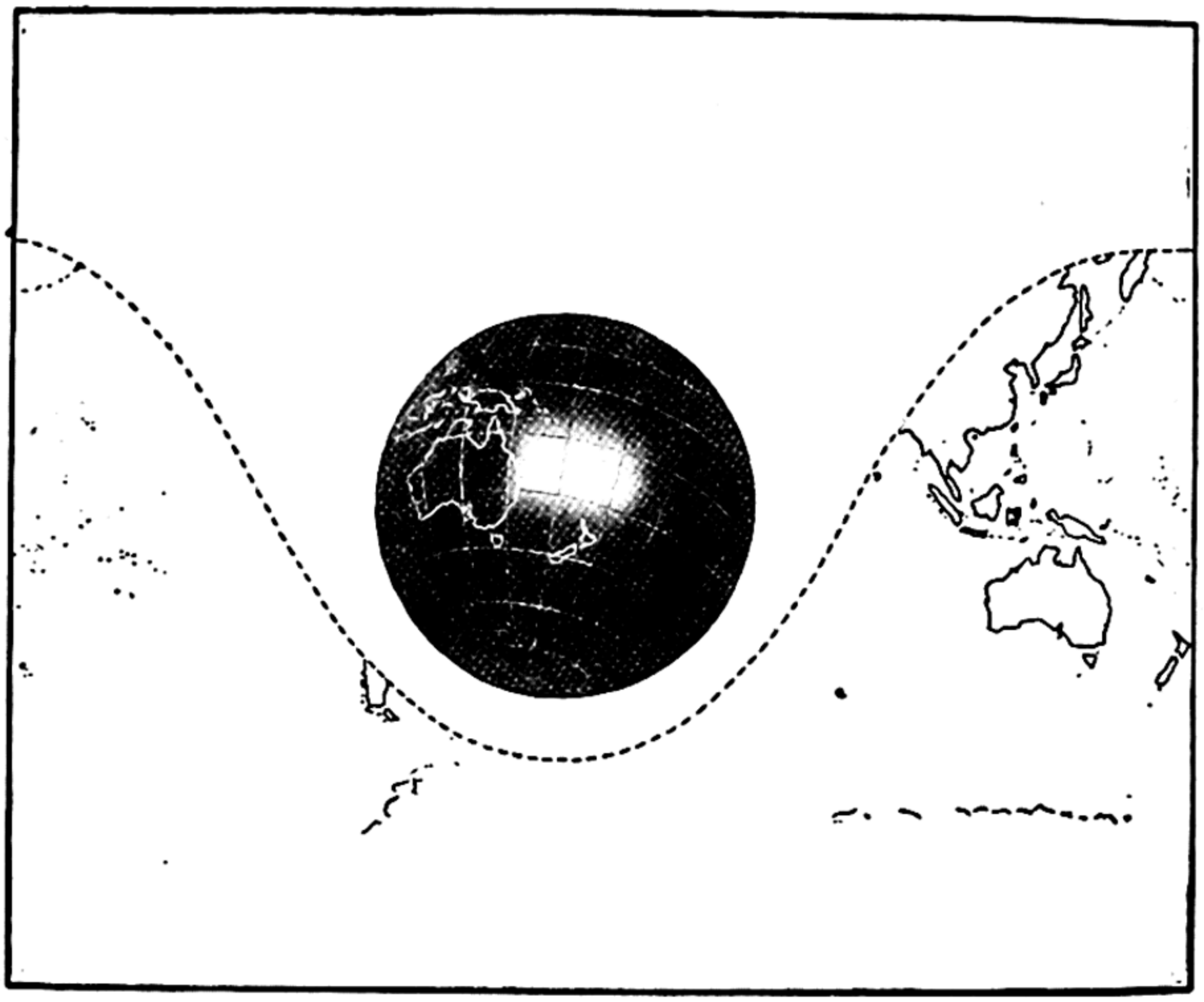


FIG. 150.—A HEMISPHERE ON THE GLOBE AND ON THE MAP.

Equator . . .	228 mm. (19 × 12), or 9 inches ($\frac{3}{4}$ × 12).
Parallel 60° and the meridians . .	114 mm. (9$\frac{1}{2}$ × 12), or 4$\frac{1}{2}$ inches ($\frac{3}{8}$ × 12).
Parallel 30° . .	198 mm. (16$\frac{1}{2}$ × 12) or 7·8 inches (·65 × 12).
Radius . . .	36·3 mm. or 1·43 inches.



[*Photo by E. J. O.*

FIG. 151.—A CRICKET BALL WITH LINES OF LONGITUDE AND LATITUDE.

SOME PROPERTIES OF THE GLOBE

Here are some points to notice on the cricket ball which can be used later on for comparison with the various projections ; the same points can of course be seen on the school globe.

THE PARALLELS

The Equator is the longest, the others diminish in length towards the poles.

Parallel 60° is half as long as the Equator.
The poles are points.
The parallels are equidistant.

The Meridians

They are equal in length.
They converge towards the poles where they meet.
They are equidistant from each other along any parallel.

Angles

Meridians and parallels cross one another at right angles.



Fig. 152.

Areas

(1) Around each pole is a series of triangles equal in shape and area.

(2) Between parallels 60° and 30° is a series of quadrilaterals equal in shape and area and larger than the triangles in (1).

(3) Between parallels 30° and 0° is another series of quadrilaterals equal in shape and area but larger than those in (2).

(4) If we take the northern or the southern hemisphere and cut it through parallel 30° we divide its surface into two equal parts. The cricket ball, for instance, has a surface area of about 26 square inches, and this is divided into four equal sections of 6½ square inches by the Equator and parallels 30° N. and 30° S.



Fig. 153.

THE MAPS OF THE CONTINENTS

The maps on the next page are drawn on various projections, but in all of them the meridians and parallels are

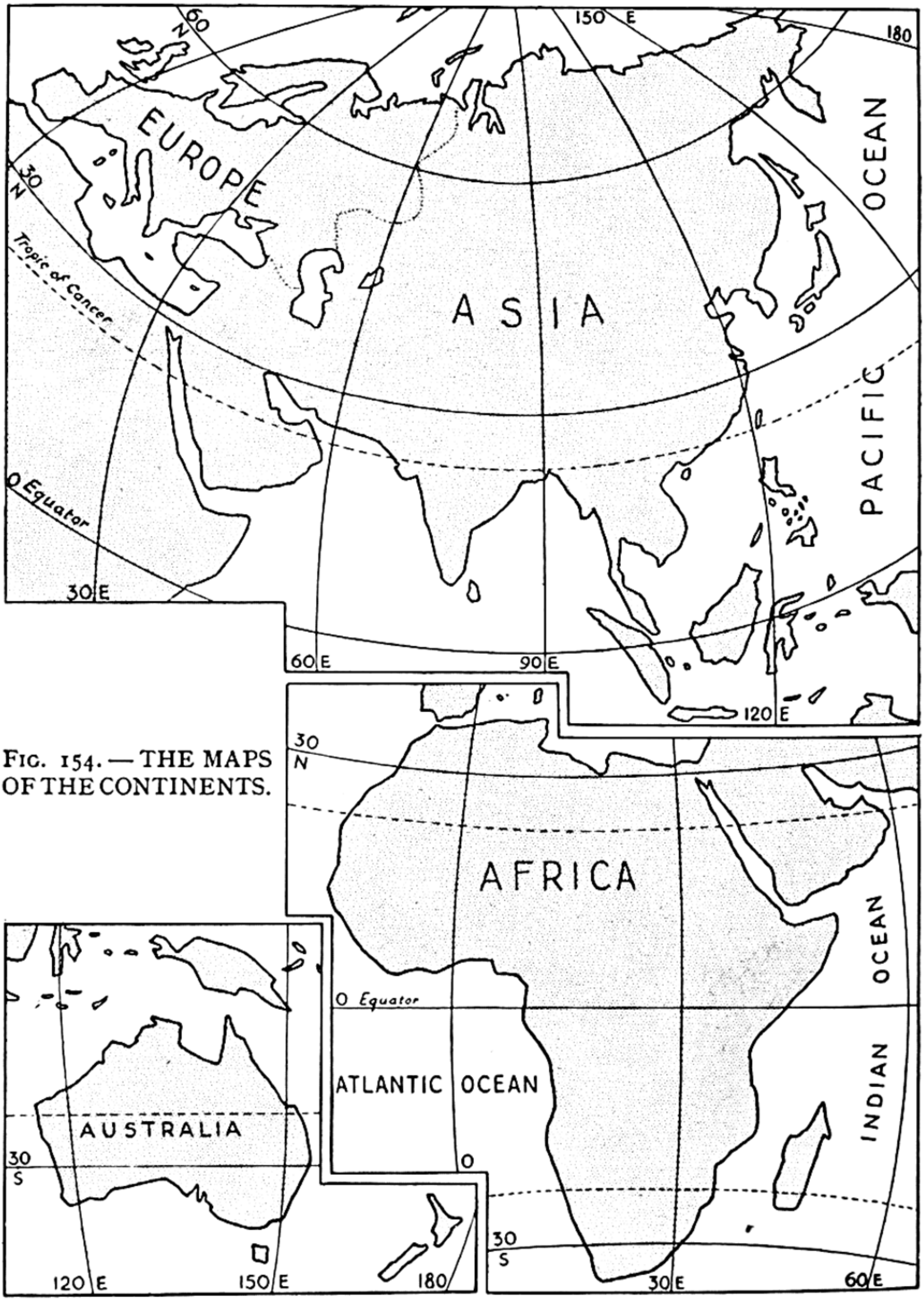


FIG. 154. — THE MAPS OF THE CONTINENTS.

drawn at intervals of 30°. They can, therefore, be easily copied on to any of the projections of the cricket ball. The map of South America must be taken directly from Fig. 158.

A SIMPLE PROJECTION OF THE CRICKET BALL

Construction

Draw a rectangle 9 inches by 4½ inches.

Divide its sides into sections of three-quarters of an inch.

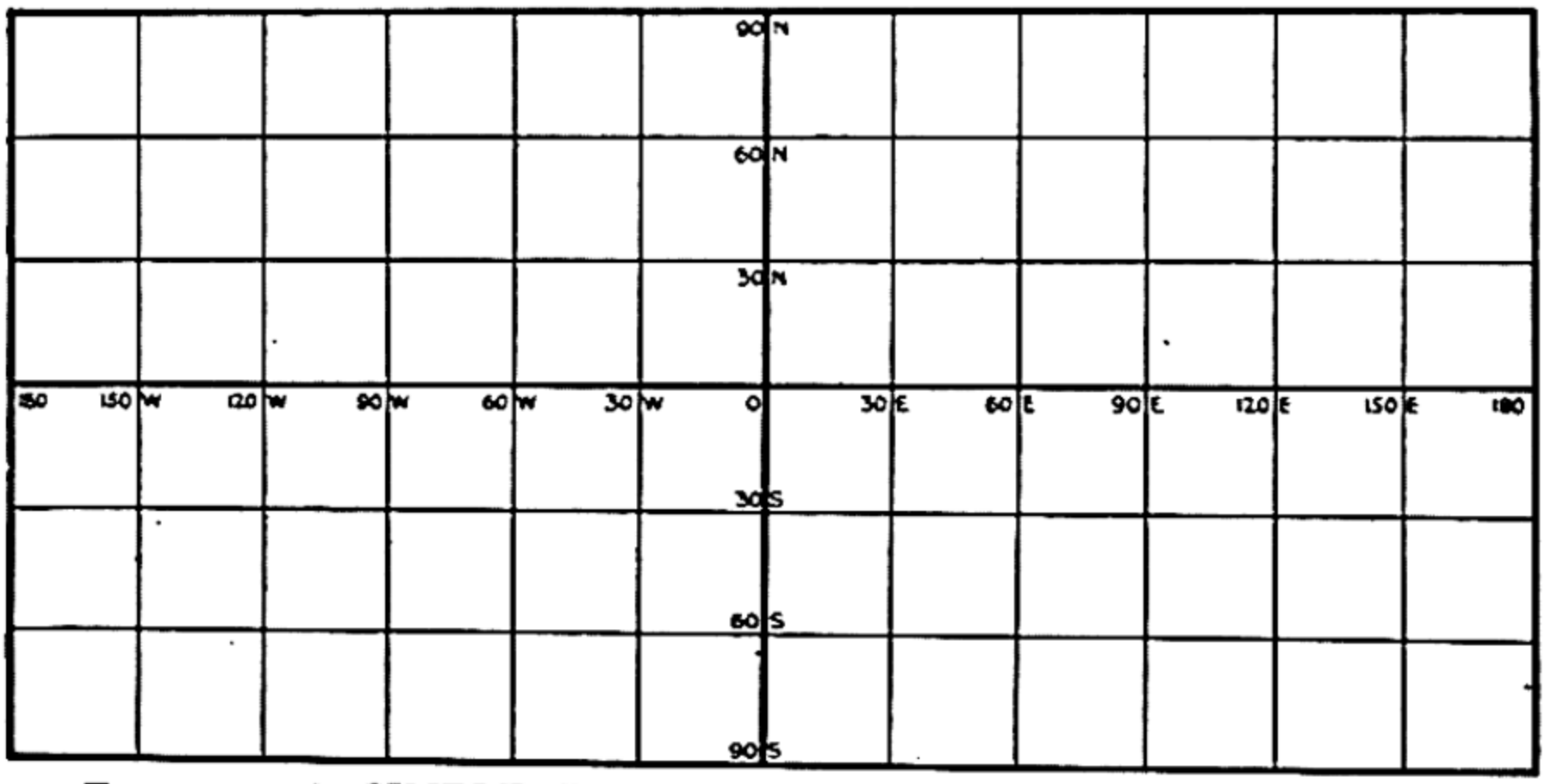


FIG. 155.—A SIMPLE PROJECTION OF THE CRICKET BALL.

Draw the meridians and parallels as shown in Fig. 155 and number them.[1]

A. 1. Draw this projection of the cricket ball.

Notes on the Projection for comparison with the cricket ball.

1. *Correct.*

The Equator and the meridians are the same length as on the ball.

The " parallels " are parallel. They are equidistant.

Meridians and parallels cross one another at right angles.

[1] The name of this projection is the Cylindrical Equidistant. If it be cut out, leaving a flange at one side, it can be converted into a cylinder.

2. *Incorrect.*

The meridians do not converge towards the poles.

The poles are lines, not points.

The parallels are all of the same length.

The quadrilaterals marked out by the meridians and parallels are all equal to one another in area instead of getting less as we go from the Equator to the poles.

The triangles round the poles have become squares in the projection.

A. 2. In what respects are the parallels in the projection correct? Where are they incorrect?

A. 3. In what respects are the meridians correct? Where are they incorrect?

A. 4. Plot the positions of the following, putting its initial against each:

London, 51½° N. 0° long.
New Orleans, 30° N., 90° W.
Cairo, 30° N., 30° E.
Shanghai, 30° N., 120° E.
Leningrad, 60° N., 30° E.
Fiji, 17° S., 180° long.
Durban, 30° S., 30° E.
Falkland Is., 52° S., 60° W.
Sydney, 34° S., 150° E.

A. 5. Draw the map of the continent of Africa on the projection (see page 152). Shade on your drawing the triangles marked out in white in Fig. 152.

THE TROPICS

If the tropics were 22½° away from the Equator instead of 23½° they would be exactly a quarter of the distance between the Equator and the poles, and the circles, Arctic and Antarctic, would be the same distance from the poles. The difference between 22½° and 23½° on the cricket ball is one-fortieth of an inch—the width of a thick pencil line.

A. 6. Draw the tropics and the polar circles on the projection.

THE CYLINDRICAL EQUAL-AREA PROJECTION

The Name

(*a*) Cylindrical: If the map is cut out it can be converted into a cylinder.

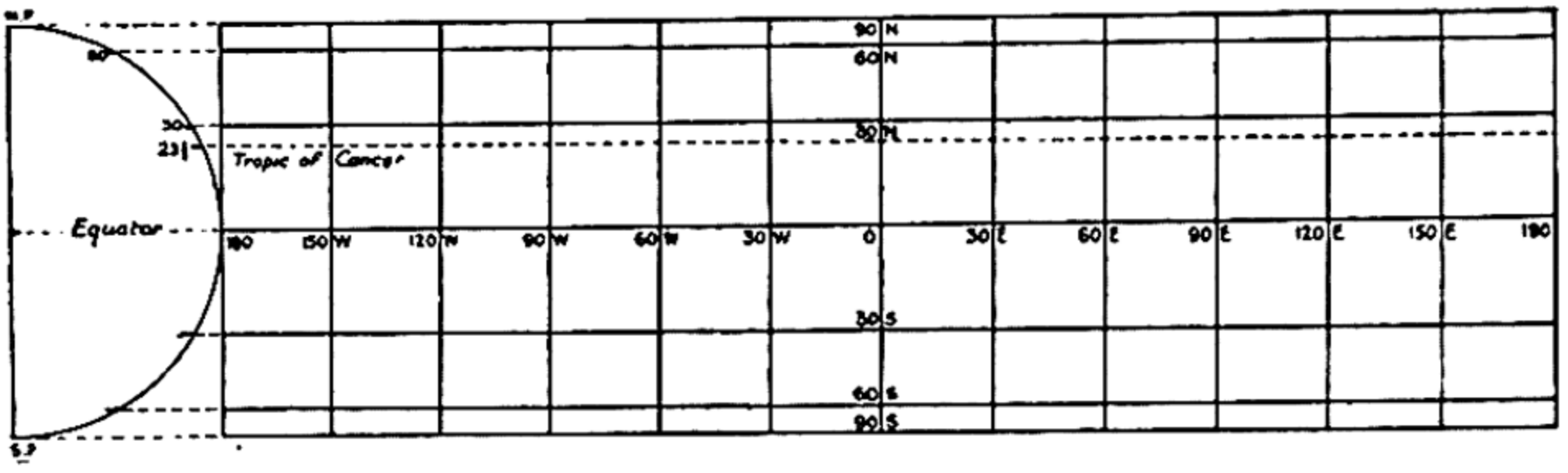


FIG. 156.—THE CYLINDRICAL EQUAL-AREA PROJECTION OF THE CRICKET BALL.

(*b*) Equal Area : Each of the rectangles on it is equal in area to the corresponding space on the cricket ball.

The whole rectangle is equal in area to the surface of the cricket ball.

The Equator and parallels 30° N. and S. divide the rectangle into four equal parts.

CONSTRUCTION

Draw a semicircle with the same diameter as the cricket ball.

Divide it into six parts to find the positions of the Equator and parallels 60° and 30°.

Draw (1) a tangent touching the Equator, and

(2) the dotted construction lines shown in Fig. 156.

Construct the rectangle, making it as long as the circumference of the cricket ball and divide it into twelve parts for the meridians.

Since the parallels in this projection are not at equal distances from one another, the Tropics and Polar Circles must be marked first on the construction circle and then projected in the same way as parallels 30° and 60°.

C. 3. Draw the Cylindrical Equal Area Projection of a cricket ball with the tropics and circles and shade the polar triangles marked out in Fig. 152.

C. 4. Plot the positions of London, New Orleans, Leningrad, Cairo, and Shanghai.

C. 5. Draw the maps of Africa, South America, and Australia.

C. 6. Make as many comparisons as you can between the parallels and meridians on this projection and those on the cricket ball.

C. 7. Explain why the name Cylindrical Equal-Area Projection is used.

The two boundary meridians on the cylindrical projections are really one and the same line. This can be understood when the map is connected into a cylinder, as in Fig. 157. Here the two meridians numbered 180° on the map become one line.



FIG. 157.—THE GLOBE AS A CYLINDER.

A NORTH-EAST LINE ON THE GLOBE AND THE MAP

On the various pictures of the cricket ball can be seen a dotted line cutting the Equator on meridian 0°. It runs N.E. in one direction and S.W. in the other, and it is possible to copy it on to the projections by noticing where it crosses the lines of latitude and longitude; or it may be plotted from the table on page 191.

C. 8. Copy the N.E.–S.W. line from the ball on to any of the projections you have drawn.

A GREAT CIRCLE ON THE GLOBE AND THE MAP

The thin rubber band round the cricket ball follows the course of the line separating day and night on December 21st, when it is noon at Greenwich. It divides the surface of the ball into two equal hemispheres and is a great circle (see page 62). Like the N.E. line, this day-and-night line



FIG. 158.

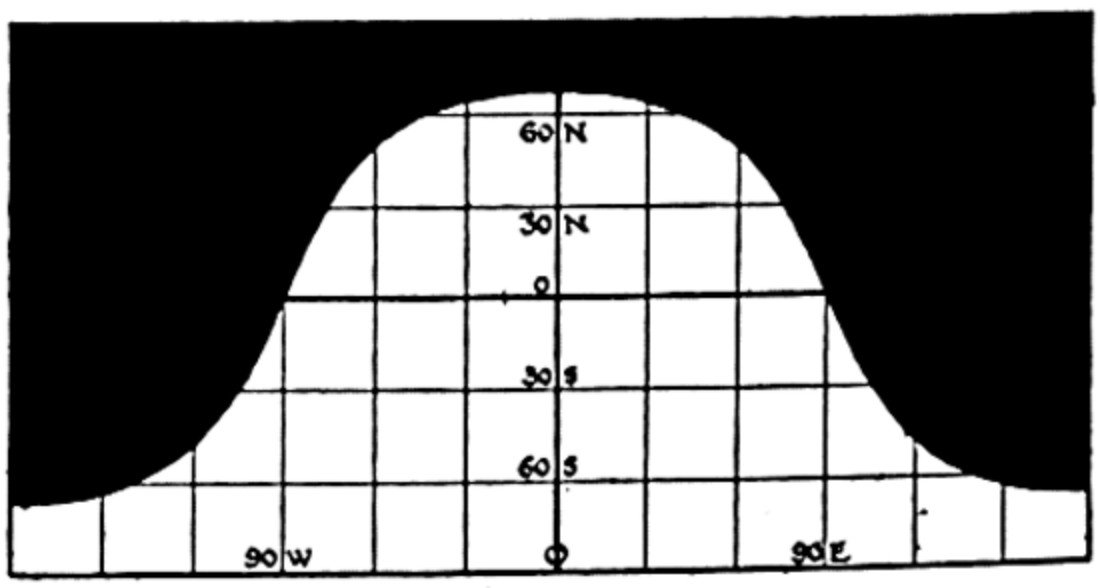


FIG. 159.—DAY AND NIGHT DRAWN FROM THE CRICKET BALL.

may be transferred to the projection from the pictures or it may be plotted from the table on page 191.

Notice that each of the four pictures of the cricket ball has at least one great circle that appears as a straight line. Fig. 151 has the equator and the central meridian, and Fig. 152 the rubber band. Fig. 158 combines these, while in Fig. 162 the meridians are straight lines.

C. 9. Draw the great circle marked on the cricket ball by the rubber band on any of the projections you have drawn.

THE SINUSOIDAL PROJECTION

In this projection the measurements of all the parallels and of the prime meridian are taken directly from the ball.

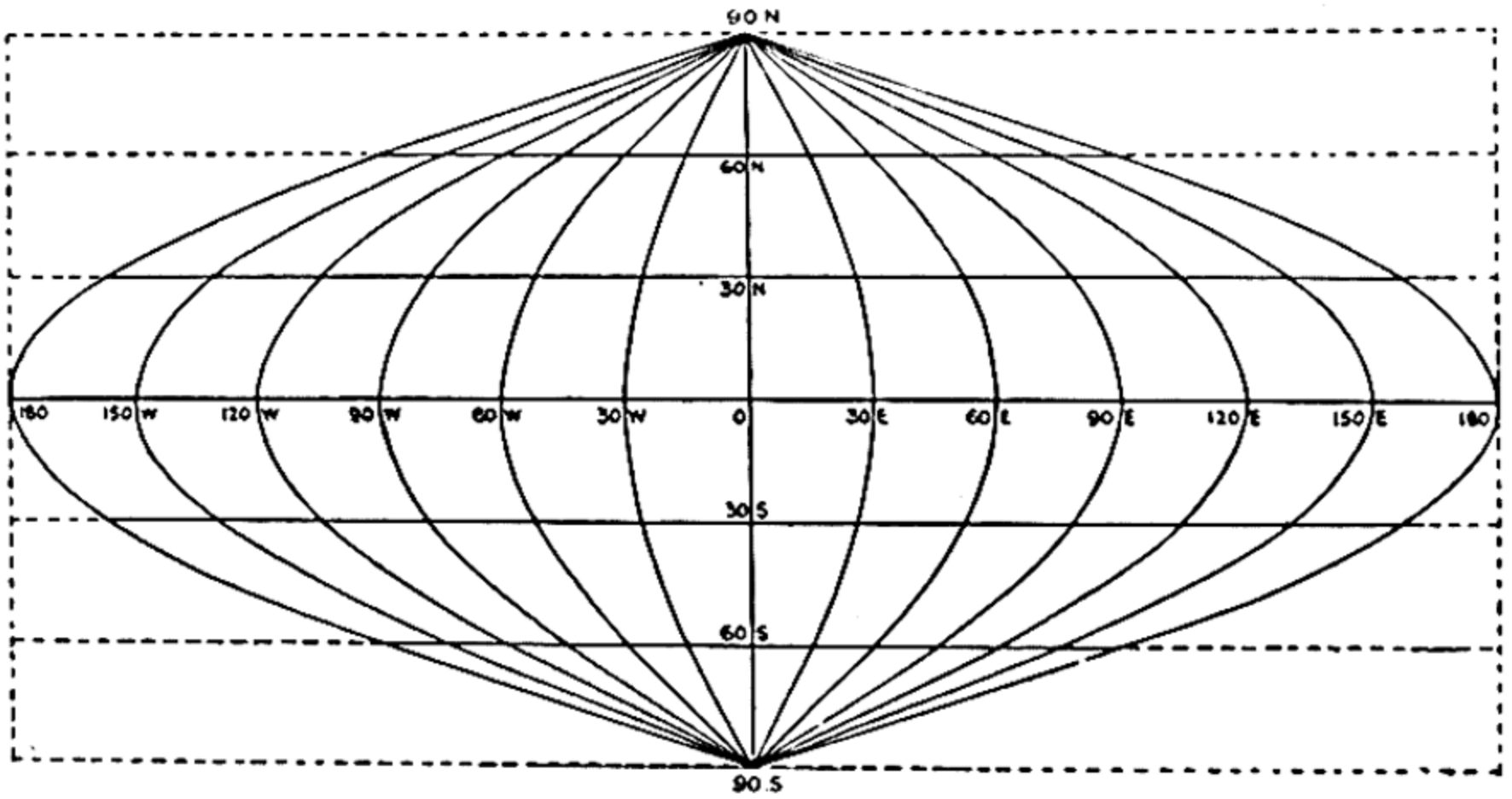


FIG. 160.—THE SINUSOIDAL PROJECTION.

CONSTRUCTION

(See "A Preliminary Exercise" on page 158).

Draw the rectangle and the parallels as for the cylindrical equidistant projection, but only as construction lines.

Draw the central meridian.

The Equator is the same length as on the ball, viz. 9 inches. Divide it into twelve equal parts ($\frac{3}{4}$ inch).

Parallel 30° is 7·8 inches on the ball. Mark off 3·9 on either side of the central meridian. Divide the whole into twelve parts (·65 inch).

Parallel 60° is $4\frac{1}{2}$ inches on the ball. Mark off $2\frac{1}{4}$ inches on either side of the central meridian. Divide the whole into twelve parts ($\frac{3}{8}$ inch).

Draw the meridians by joining up the points on the parallels.

(*Note.*—The outer meridians between the pole and parallel 60° are so nearly straight lines that a ruler may be used with advantage.)

One great value of this projection is that it is "equal area," i.e. when drawn the correct size every quadrilateral on it, and every triangle, is the same size as the corresponding figure on the cricket ball. On the map of the world "equal area" is not altogether suitable, and so the term "equivalent" is used.

In atlases it is often called the Flamsteed or Sanson-Flamsteed Projection.

C. 10 (*a*) Work the Preliminary Exercise given below, using the inch measurements.
C. 11 (*b*) Draw the tropics and the polar circles. Add the positions of London, Cairo, Shanghai, Leningrad, and New Orleans.
C. 12 (*a*) Draw the sinusoidal projection, using the metric measurement on page 150.
C. 13 (*b*) Draw the tropics and the polar circles. Add the positions of London, Cairo, Shanghai, Leningrad, and New Orleans.
C. 14. Compare the projection with the cricket ball, saying where it is correct and where incorrect.
C. 15. Add the day-and-night line for December 21st, at Greenwich noon (see page 191).
C. 16. Add a S.W.–N.E. line (see page 191).

A PRELIMINARY EXERCISE

As the drawing of the curves may present difficulties, it is a good plan to join up the points with a ruler as a preliminary

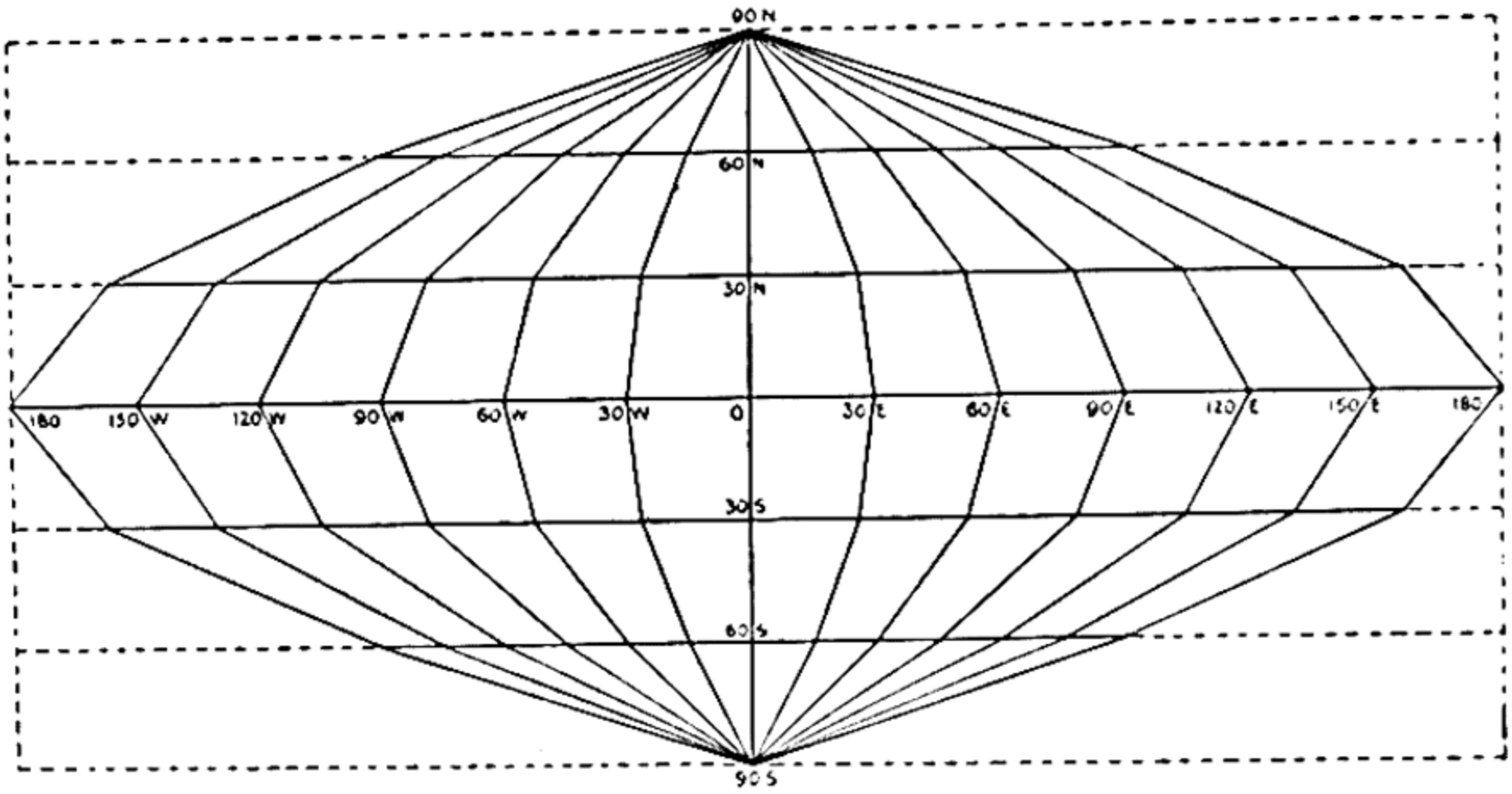


FIG. 161.—A PRELIMINARY EXERCISE.

exercise. The resulting projection has no special name, but it can be used quite well for comparisons with the globe. London, etc., may be plotted on it.

POLAR PROJECTIONS

In all the projections we have so far discussed, the Equator has been a straight line across the middle of the map. These are in consequence called " equatorial projections." In the next group we shall deal with the " polar projections." In these the pole is in the middle with the meridians radiating from it like the spokes of a wheel, while the parallels are concentric circles whose distances apart vary with the type of projection.

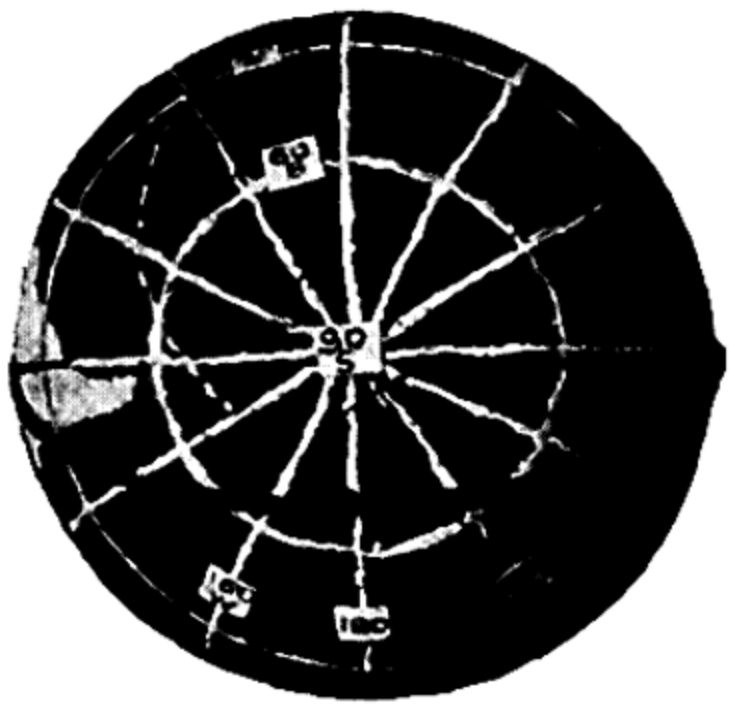


FIG. 162.

THE POLAR EQUIDISTANT PROJECTION

The Polar Equidistant is not only easy to construct, but it is largely employed for printed polar maps, including those used by great explorers.

Construction

Draw a circle with a radius equal to the distance from the pole to the equator on the cricket ball, measured on the surface with a string ($2\frac{1}{4}$ inches or 57 millimetres).

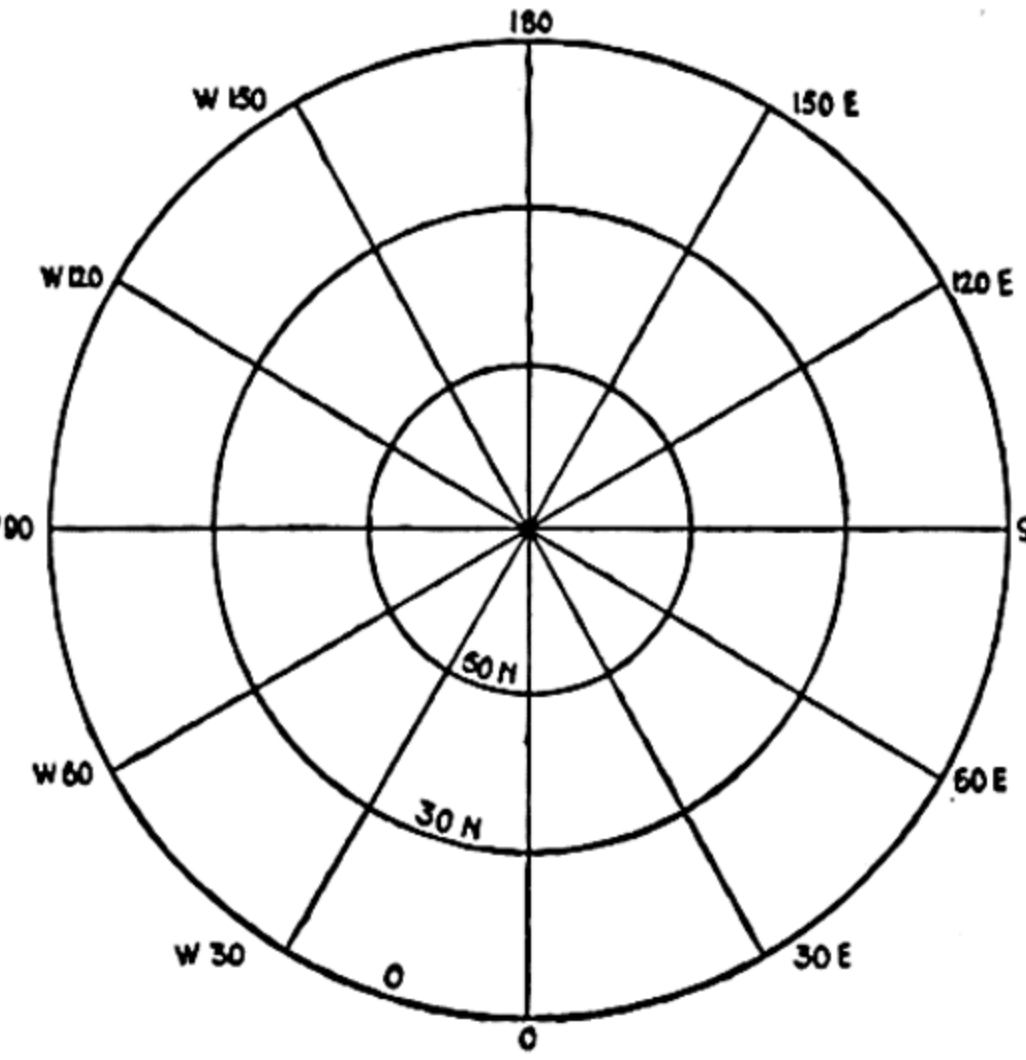


Fig. 163.—THE EQUIDISTANT POLAR PROJECTION.

Divide its circumference into twelve parts, draw the meridians and number them for the northern hemisphere.

Draw parallels 30° and 60° concentric with the Equator. (For 30° the radius is $1\frac{1}{2}$ inches or 38 mm. : for 60° it is $\frac{3}{4}$ inch or 19 mm.)

C. 1 (*a*) Draw the Polar Equidistant Projection of the cricket ball. Add the Tropic of Cancer and the Arctic Circle.

(*b*) Compare the projection with the cricket ball (page 159), and write down the points under two heads : correct and incorrect.

(*c*) Plot the position of the places given on page 154 that are in the northern hemisphere and name them.

(*d*) Add that part of the day-and-night line for December 21st, at Greenwich noon, that comes within the northern hemisphere, and the corresponding section of the S.W.–N.E. line (see page 191).

(*e*) Draw those parts of S. America and Africa that lie north of the Equator.

C. 2 (*a*) Draw a projection for the southern hemisphere and put in the places, with their names, on page 154 that fall within it.[1]

(*b*) Add that part of the day-and-night line for December 21st, Greenwich noon, that comes into the southern hemisphere and the corresponding section of the S.W.–N.E. line (see page 191).

(*c*) Draw Australia and those parts of S. America and Africa that lie south of the Equator.

[1] In numbering the meridians on a polar projection take a piece of any meridian running *up* to the north and decide east and west from this ; or better, visualize the globe and the positions of India and America on either side of the Greenwich meridian.

MERCATOR'S PROJECTION[1]

This projection was invented in the sixteenth century by a Fleming whose name was Kremer. After the fashion of the time, the name was Latinized and became Mercator. The projection was afterwards perfected by two English mathematicians, Edward Wright and Henry Bond. Its great value lay in the fact that all rhumb lines or compass directions on it are straight lines. If a captain had to take a ship from Ushant to Barbados he had merely to place a ruler on the map between the two places and his course was settled for him. It was not the shortest course, but that was not of first importance in the days of sails.

HOW THE MERCATOR PROJECTION WAS CONSTRUCTED

In the lower left side of the illustration is a piece of the same projection as there is in Fig. 155, but with extra lines

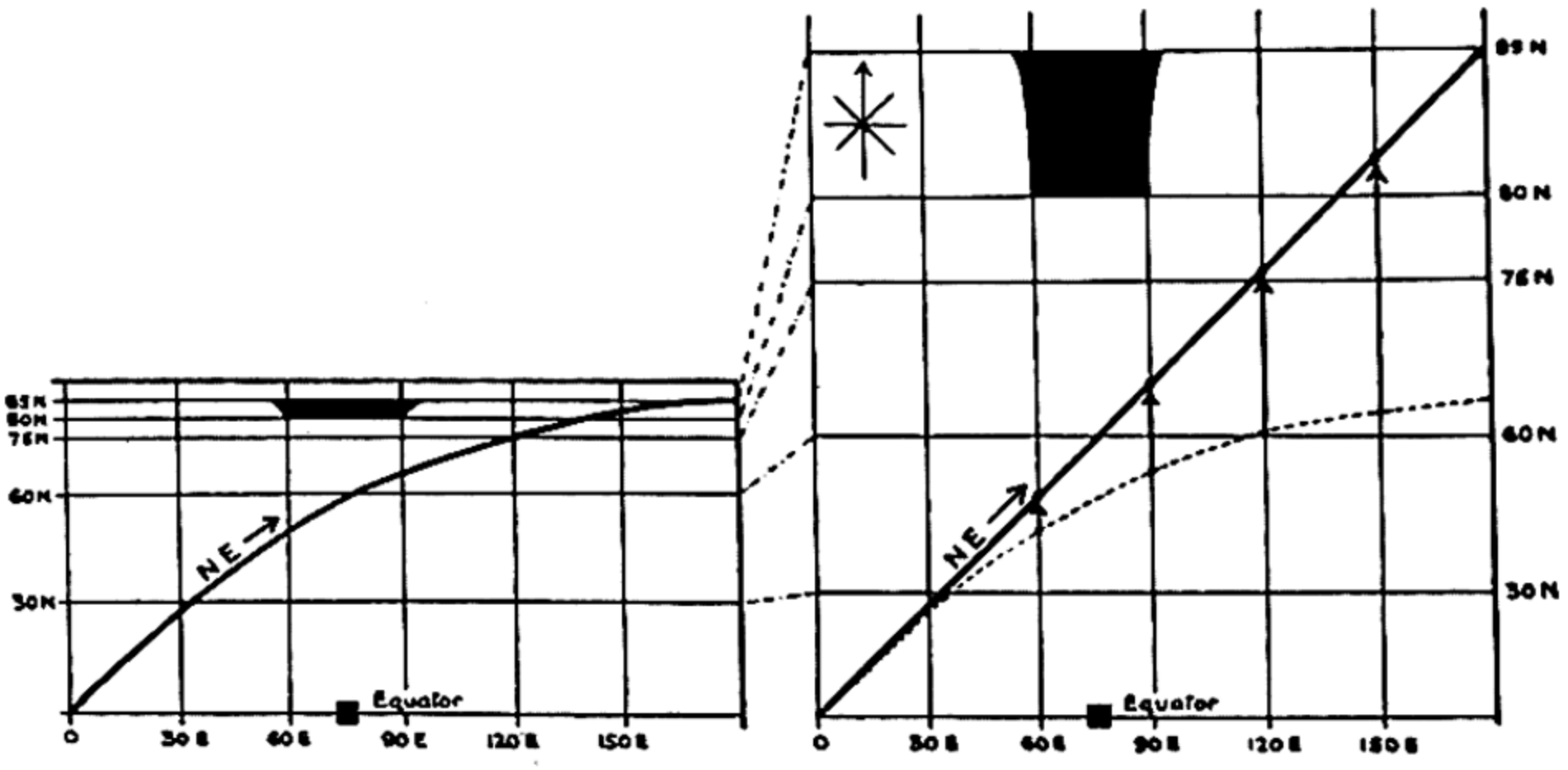


FIG. 164.—MERCATOR MADE THE N.E. LINE STRAIGHT.

drawn for parallels 75, 80, and 85. East and west directions on it, and those going north and south, run in straight lines parallel with the edges of the map. All other directions, how-

[1] The trouble this man must have taken to squash a nearly round thing out flat on to a single piece of paper without losing any of it can only be appreciated by scientists like myself who have made a long study of geography.—Mr. Punch on Mercator.

ever, follow curved lines, and as an example the N.E. line has been drawn. At the beginning it makes an angle of 45° with the Equator, but the farther it goes the more it inclines, until on meridian 135° it is almost parallel with the Equator. This makes such a map a very difficult one on which to lay a course or read compass directions.

Mercator's great work was to make a curved line into a straight one. This he did by the very simple method of pushing the various points on it due northward as in the right half of the illustration, where the dotted line is the same shape as the N.E. line on the left. The nearer to the pole the line gets the bigger is the distance the curved line has to be pushed before it becomes straight, until at the top of the map the five degrees of latitude between parallels 80° and 85° cover a greater distance than the thirty degrees near the Equator.

Looking at it another way, we can say that Mercator took the twisty dotted line drawn on the cricket ball in Fig. 151 and converted it into the straight N.E. line in Fig. 164.

Not only is the north-east direction made into a straight line, but all the other direction lines become straight at the same time, so that the compass points in the left upper section of the map can be used on any part of it.

D. 1. Draw a projection of the cricket ball on Mercator's Projection.

$0° - 30° = \text{radius} \times \cdot 549$

$0° - 60° = \text{radius} \times 1 \cdot 317$

See table on page 192.

D. 2. Add the day-and-night line for December 21st, at Greenwich noon and the S.W.–N.E. Rhumb Line.

D. 3. Draw North America on it and compare the length and breadth of the continent on this projection and on the globe.

D. 4. In what ways is the Mercator projection correct and in what ways incorrect?

AREAS AND SHAPES ON THE MERCATOR MAP

On both the projections in Fig. 164 there is a square on the Equator which has sides of about three hundred and fifty

miles. A square of the same size has also been drawn on both between parallels 80 and 85. In the first case it has been stretched east and west only; in the second it has been pulled northward as well. It is because of this double stretching that Greenland looks so much larger than India on the Mercator projection, although on the globe they are about the same size.

If we take a small square, say a mile each way, at various latitudes and draw it on the Mercator map, we shall find that it always retains its shape no matter how much its size may be exaggerated.

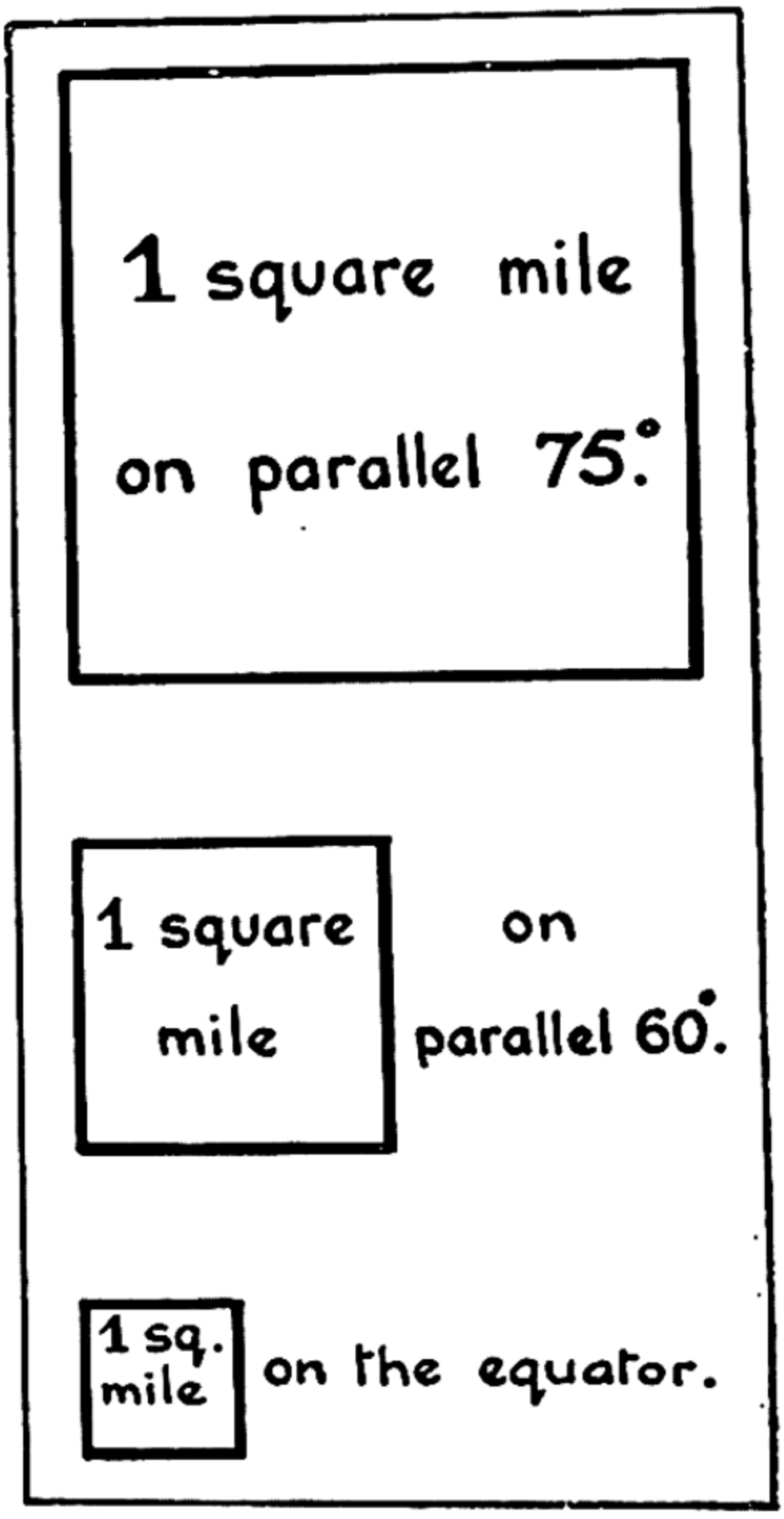
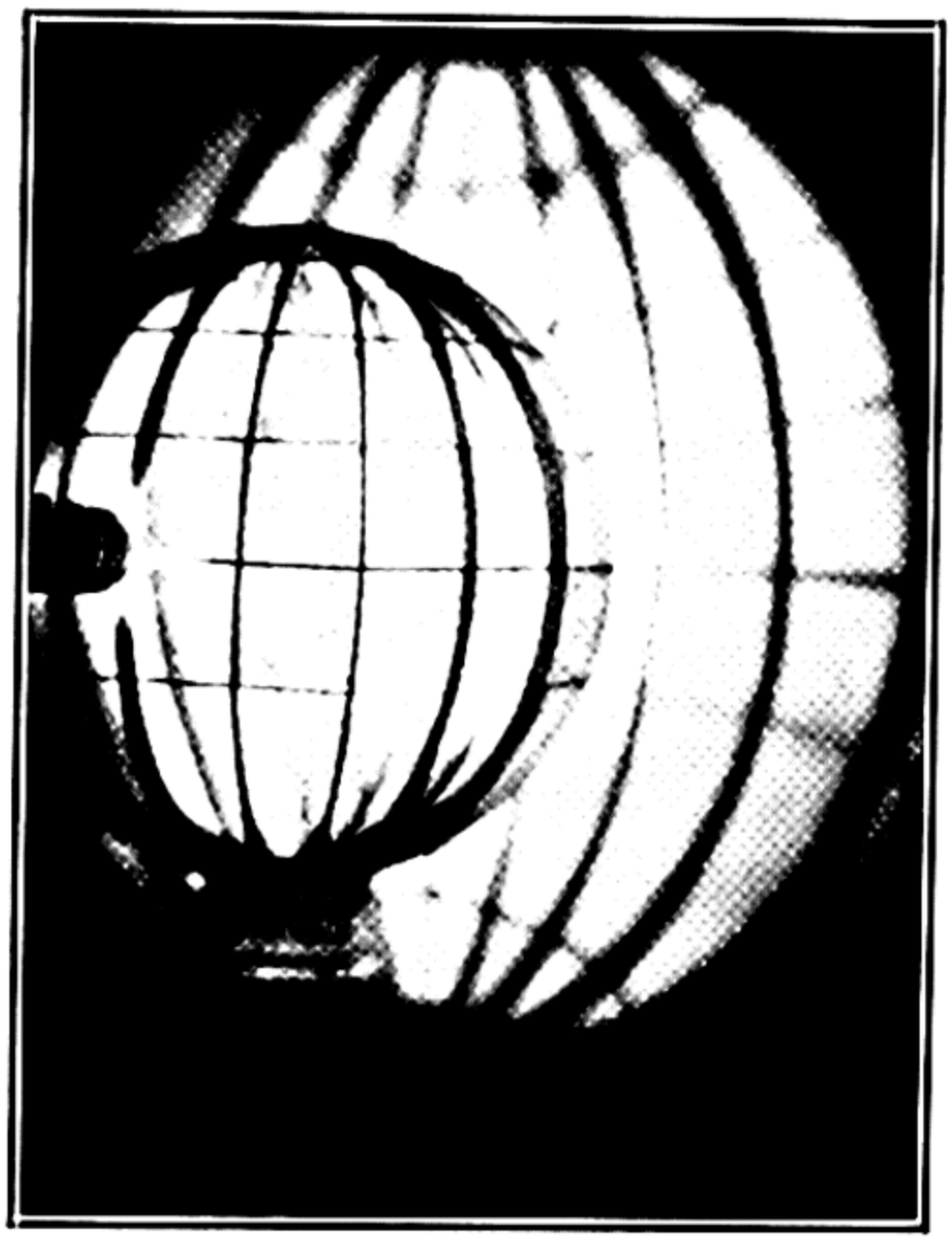


FIG. 165.—A MILE ON THE MERCATOR MAP.

THE SHADOW PROJECTIONS

In Fig. 166 is a "skeleton globe" with its meridians made of cardboard and its parallels of knitting wool (parallel 60° S. is missing). On one side its equator just touches a sheet of white paper. On the other side is an ordinary electric torch, which throws the shadows of the parallels and meridians on to the paper. This shadow is the Equatorial Stereographic Projection, a projection that is often used for maps of the hemispheres.

If the light is moved slowly towards the centre of the globe, the shadow will get bigger and bigger and the meridians



[*Photo by S. Wyles.*

FIG. 166.—AN EQUATORIAL SHADOW PROJECTION.

straighter and straighter. By the time the centre is reached, the poles will be off the map and the meridians will be parallel straight lines. We shall then have the Central Projection.[1] This is one which the captain of a liner crossing the Atlantic or the Pacific uses to find his great-circle route, for all straight lines on the central projection are great circles on the globe.

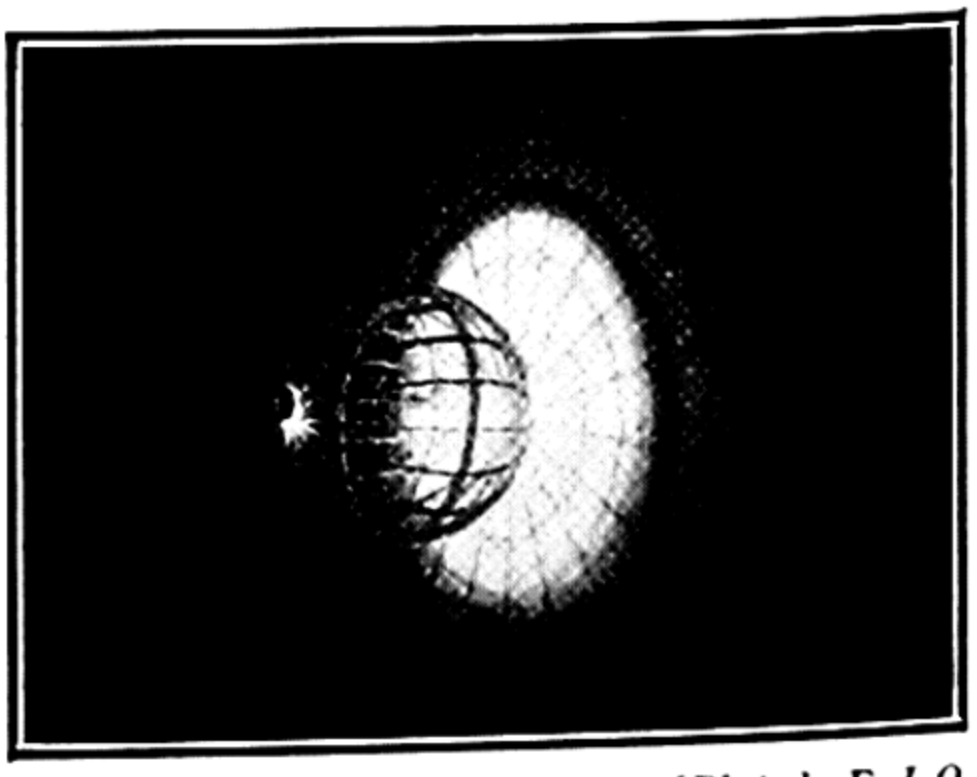
Now let the globe be turned till one of the poles touches the sheet on which the shadow is cast. When the light is put at the other pole (in the corresponding position to the light in Fig. 166) a projection is formed with a spider-web arrangement of meridians and parallels similar to those already dealt with and having the pole as centre and the Equator as the boundary. This is the Polar Stereographic Projection.

If the light is now moved to the centre, the Equator goes off the map and we have the Polar Central Projection.

THE STEREOGRAPHIC POLAR PROJECTION

CONSTRUCTION

Draw a circle with the same diameter as the cricket



[*Photo by E. J. O.*

FIG. 167.—A POLAR SHADOW PROJECTION.

[1] Sometimes called the Gnomonic Projection.

ball and divide it to obtain the positions of the Equator and parallels 30° and 60°. Draw a tangent to represent the sheet of paper that touches the pole. Draw lines through the point where the light is supposed to be, as in the diagram, and complete the projection.

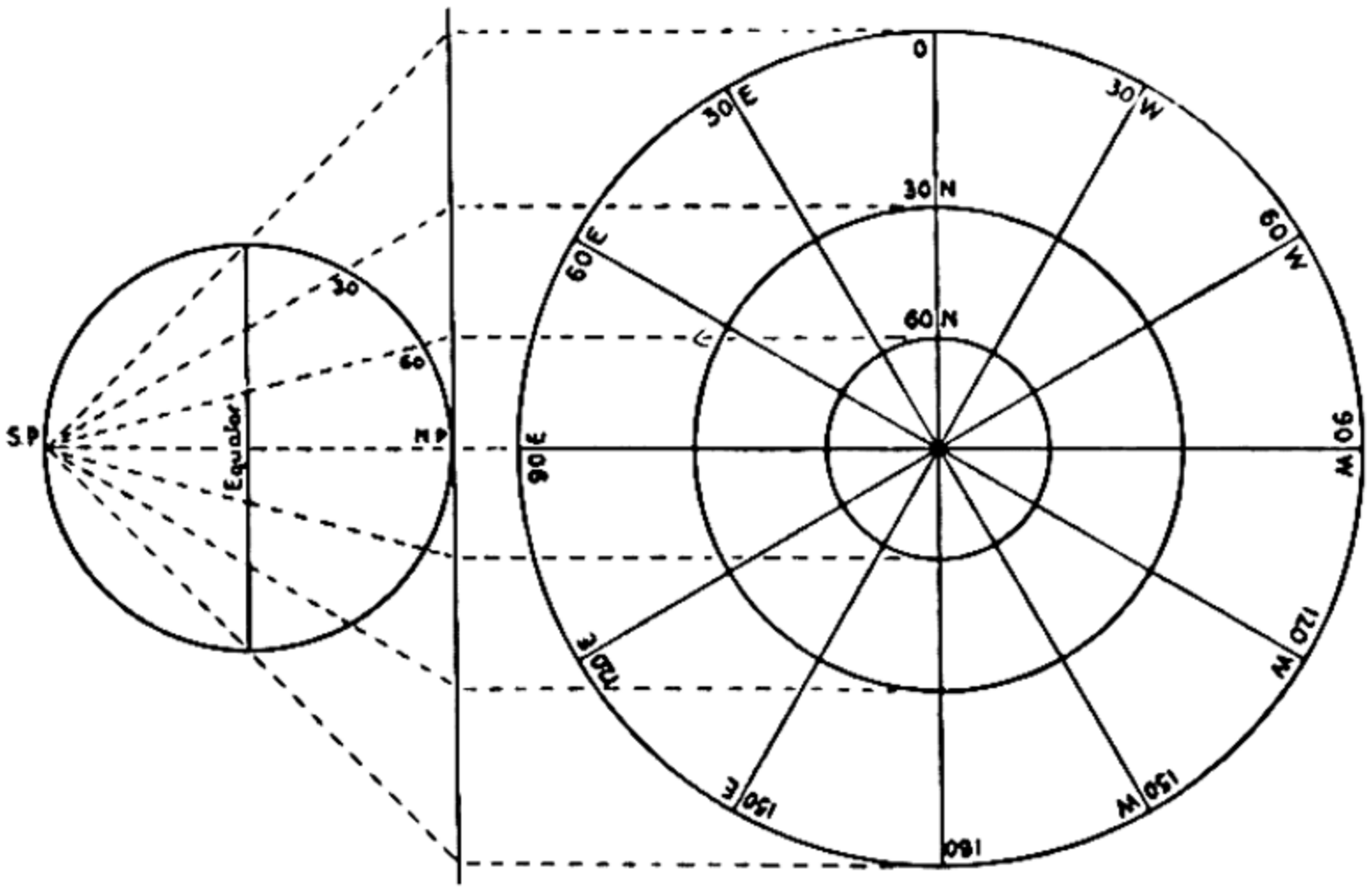


FIG. 168.—STEREOGRAPHIC POLAR PROJECTION (see Fig. 167).

D. 5. Draw the Stereographic Polar projection for the southern hemisphere.

D. 6. Add (*a*) the day-and-night line for December 21st, (*b*) the N.E.–S.W. line, (*c*) Australia and parts of S. America and Africa, (*d*) the Antarctic Circle and the Tropic of Capricorn.

D. 7. Draw the Stereographic Polar projection for the northern hemisphere.

D. 8. Add (*a*) the day-and-night line for December 21st, (*b*) the N.E.–S.W. line, (*c*) Shanghai, Leningrad, London, New Orleans, Cairo, (*d*) the Arctic Circle and the Tropic of Cancer.

THE STEREOGRAPHIC EQUATORIAL PROJECTION

An important feature of the Stereographic is that all circles on the globe are represented on it either by circles or straight lines. When, therefore, the necessary points have been fixed by construction, the projection can be completed by drawing arcs of circles through them.

Construction

Draw a circle with the same diameter as the cricket ball. Divide its circumference to show the position of the Equator

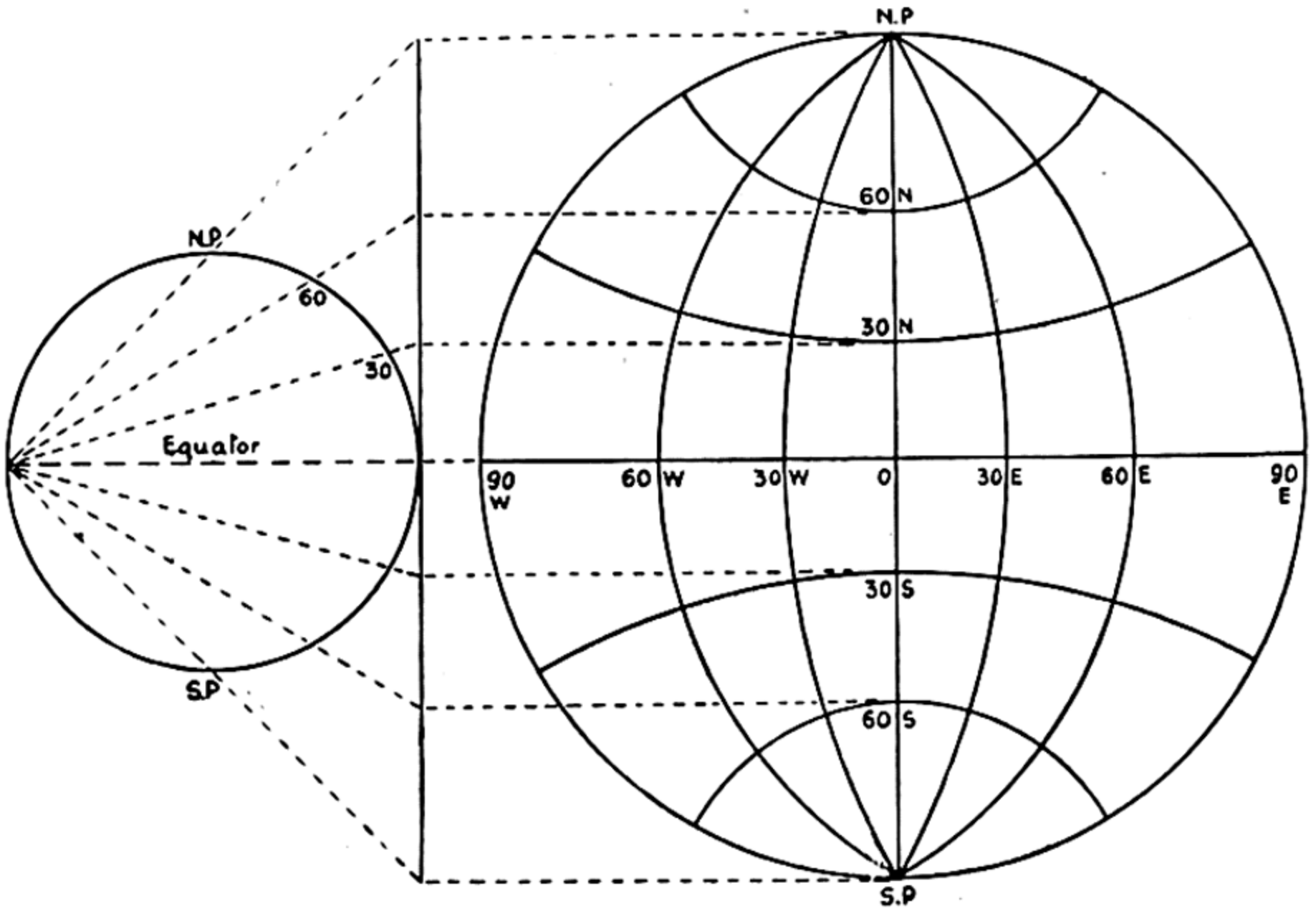


Fig. 169.—STEREOGRAPHIC EQUATORIAL PROJECTION (see Fig. 166).

and parallels 30° and 60°. Draw a tangent touching the Equator and complete the construction of one hemisphere as in Fig. 169.

The outer circle is divided into equal parts and the divisions along the Equator are the same as those on the central meridian.

D. 9. Draw the Stereographic Equatorial Projection of the cricket ball (one hemisphere), and compare it with the picture (Fig. 166). Add (*a*) the tropics, (*b*) the day-and-night line for December 21st, and (*c*) the N.E. line.

CONICAL PROJECTIONS

These form a very important group, but here we can consider only one case, that of the Simple Conical Projection.

Construction

The semicircular part of Fig. 171 is a Simple Conical Projection, and if it be cut out it can be shaped into a cone that can be made to fit over the globe, in the manner indicated in the other part of the diagram. The apex of the cone will be directly over the north pole and the thick line will touch parallel 30° all round. This is the Standard Parallel. The distance between this and the other parallels is the same as their distances apart on the globe, measured along the surface (e.g. 19 mm. in the case of the cricket ball).



[Photo by E.J.O.

FIG. 170.—THE SIMPLE CONICAL PROJECTION.

D. 10. Draw a Simple Conical Projection of the cricket ball with Standard Parallel 30° (northern hemisphere), proceeding thus:

(*a*) Draw a circle the size of the ball.

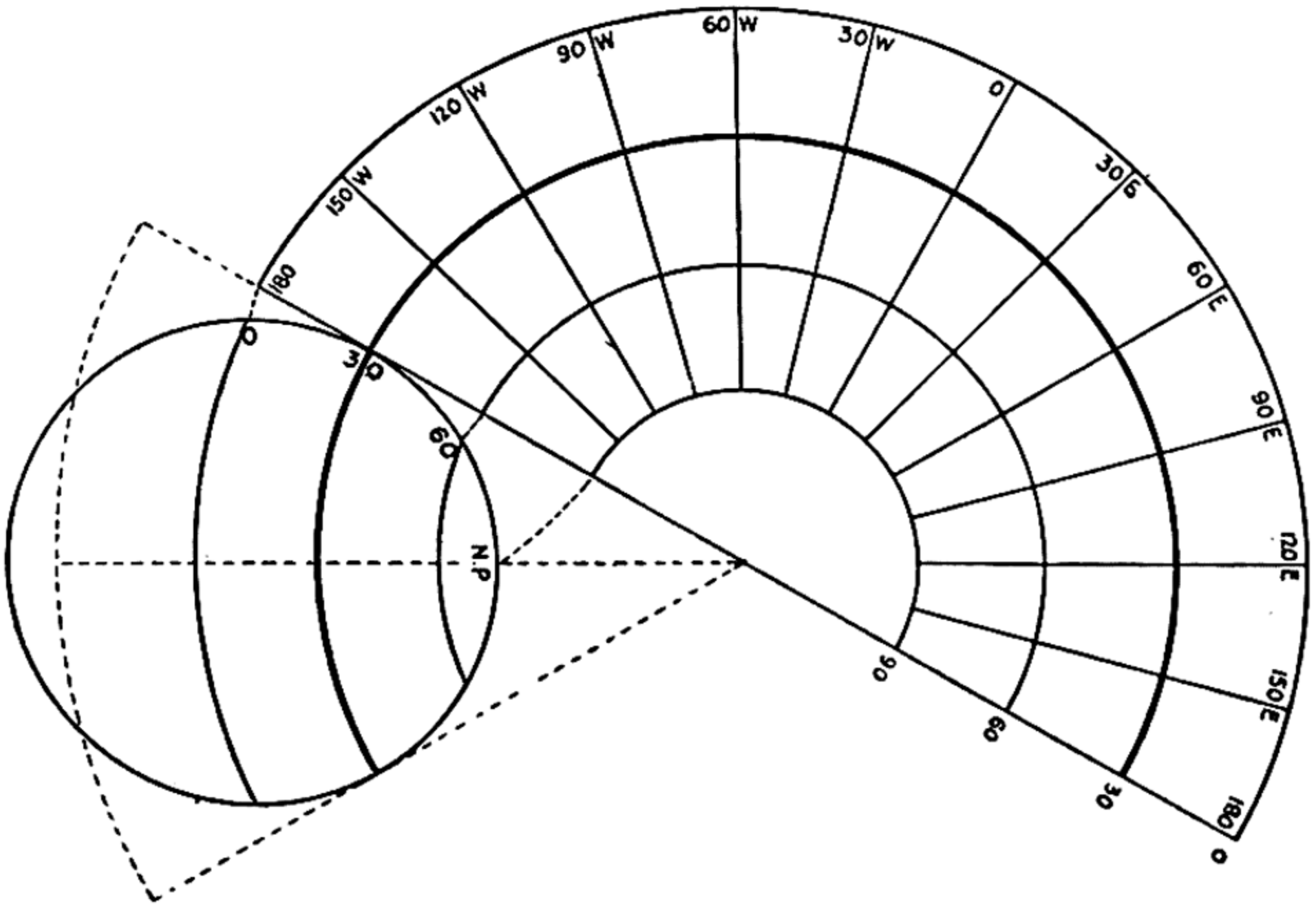


FIG. 171.—THE SIMPLE CONICAL PROJECTION (see Fig. 170).

(*b*) Draw tangents at each end of parallel 30° N. to meet as at the apex of the cone.

(*c*) Follow the diagram, omitting the parallels on the "globe."

D. 11. Criticize the projection (noticing areas, shapes, directions, parallels, etc.).

D. 12. Add (*a*) London, Shanghai, Leningrad, Cairo, New Orleans, (*b*) a N.E.–S.W. line, (*c*) the day-and-night line for Dec. 21st, (*d*) the Arctic Circle and the Tropic of Cancer.

NOTES ON SOME COMMON PROJECTIONS USED IN THE ATLAS

Bonne.—Imagine the parallels in the Sinusoidal being bent into arcs of concentric circles before the meridians are drawn. Like the Sinusoidal, the Bonne is an "equal-area" projection. It is much used for maps of Eurasia. See page 152.

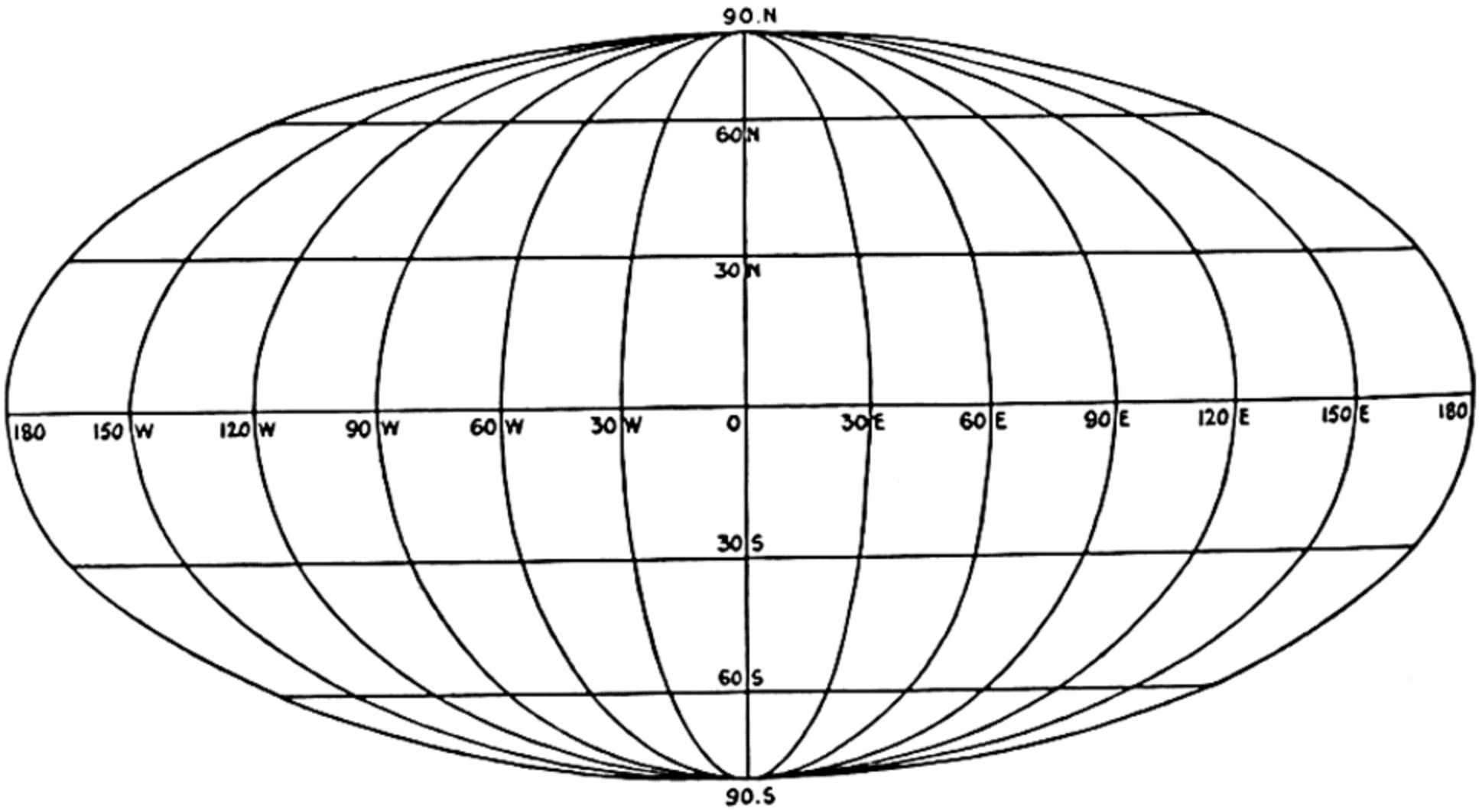


FIG. 172.—MOLLWEIDE'S "EQUAL-AREA" PROJECTION.

Mollweide.—This may be considered as the Sinusoidal with its outline smoothed into an ellipse. It is an "equal-area" or equivalent projection like the Sinusoidal and the Bonne. The meridians are equally spaced, but the parallels are not. Meridians 90° E., and 90° W. form a circle and enclose a hemisphere.

Lambert.—The full name is Lambert's Equivalent Azimuthal, a high-sounding title that is very easy to understand.

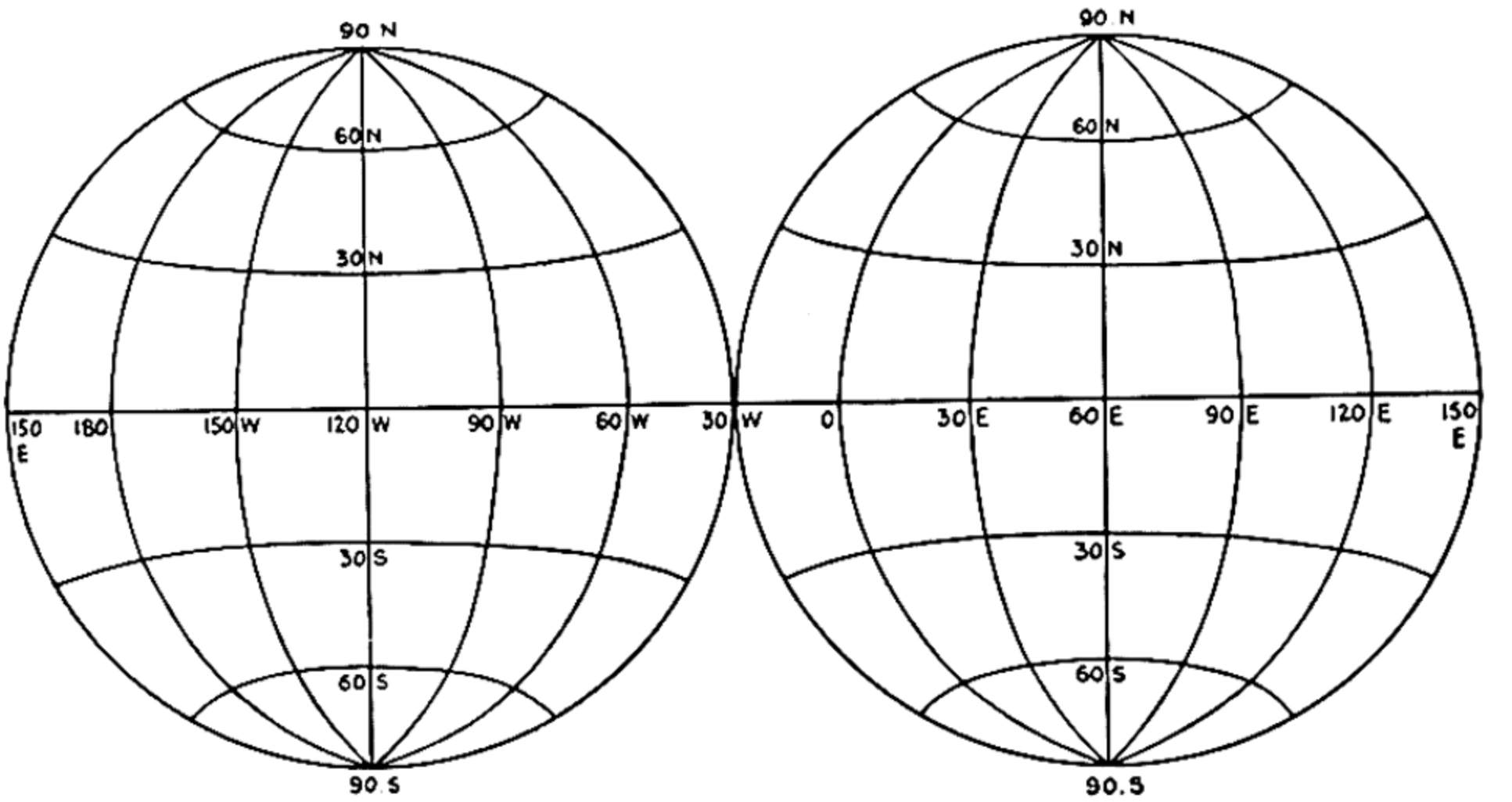


FIG. 173.—LAMBERT'S "EQUAL-AREA" PROJECTION.

The meaning of Equivalent has been explained. In an Azimuthal projection all straight lines radiating from the central point are Great Circles. "Zenithal" is sometimes used in place of Azimuthal. Fig. 173 may be recognized as a Lambert by the "flattening" of parallel 60°.

Gall.—This projection is now often used in atlases in place of the Mercator. It is drawn on a cylinder that cuts the sphere along parallels 45° N. and S. The Gall can easily be distinguished from the Mercator by the shape of Greenland, which it shortens from north to south.

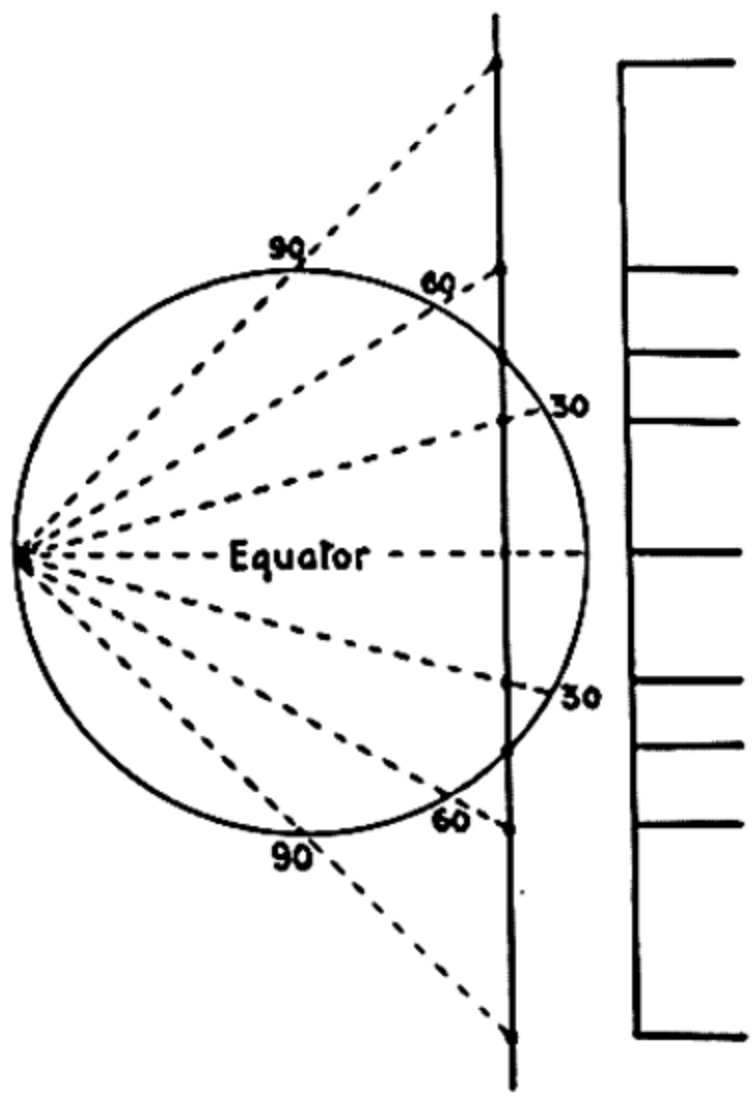


FIG. 174.—GALL'S PROJECTION CONSTRUCTION TO SHOW HOW THE DISTANCES BETWEEN THE PARALLELS ARE FOUND.

All the projections that have been discussed so far are suitable for maps of the whole globe. For maps of small portions of it, e.g. those made by the governments of Britain, France, Germany and so on, for their respective countries, a number of other projections are used. The simplest of these is that on which most of the Ordnance Maps of Britain are drawn (Cassini's rectangular co-ordinate system). Considered from one point of view, this is merely an extension of the offset method described in Chapter One. The long line drawn from one end of the playground in Fig. 1 has its counterpart in a meridian drawn right through the centre of the country, and from this offsets are run off at right angles to points on the coast, to towns inland, the tops of mountains and other important points. The distance from the meridian to any of these points is measured (or rather calculated) along a great circle. The great circle cuts the meridian at right angles, just like the offsets in Chapter One, and the plotting is done in just the same way.

QUESTIONS ON CHAPTER FOURTEEN

A. 1. Why are map projections necessary? What are some of the drawbacks connected with them?

A. 2. In testing a projection, what questions do you ask regarding (*a*) meridians, (*b*) parallels, (*c*) their intersections?

B. 1. What is the value of the Mercator map? Which parts of the globe are most correctly represented on it, and which least correctly?

B. 2. Which of the projections in this chapter seems to represent the globe best? Why do you think so?

C. 1. In looking at a new map of the world on an unknown projection, how would you judge the accuracy of the shapes and areas of the countries on it?

C. 2. The projections in this chapter are grouped for convenience under the heads "shadow," "polar," etc. Make a list of those that can be classified under more than one heading; add details in each case.

D. 1. What features are common (*a*) to all cylindrical projections, (*b*) to all polar projections?

D. 2. In which projections are the following always straight lines: (*a*) great circles, (*b*) rhumb lines?

Chapter Fifteen

SURVEYING

MAGNETIC COMPASS SURVEY

A SHIP travels 36 miles northward, 41 miles north-eastward, 63 miles southward, and 29 miles westward. Knowing these distances and directions, we can draw a map of its course, and provide a very simple illustration of the way in which a compass survey is carried out.

A. 1. Draw the course of the ship on a scale of 10 miles to an inch.

In the compass used for surveying the edge of the card is marked off in degrees, and sights are provided to ensure that the direction can be accurately read. The relation between the degrees and the cardinal points can be understood from Fig. 176.

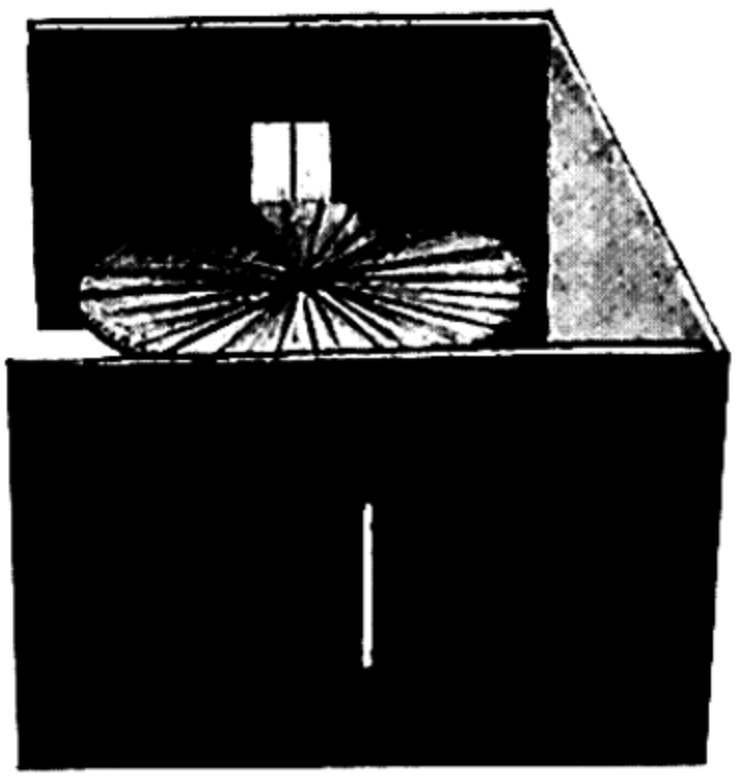


FIG. 175.—A HOME-MADE SURVEYING COMPASS.
The box opened to show the card and sight.

In Fig. 175 is a home-made box compass with its lid removed. The card completely covers the needle and is divided round its

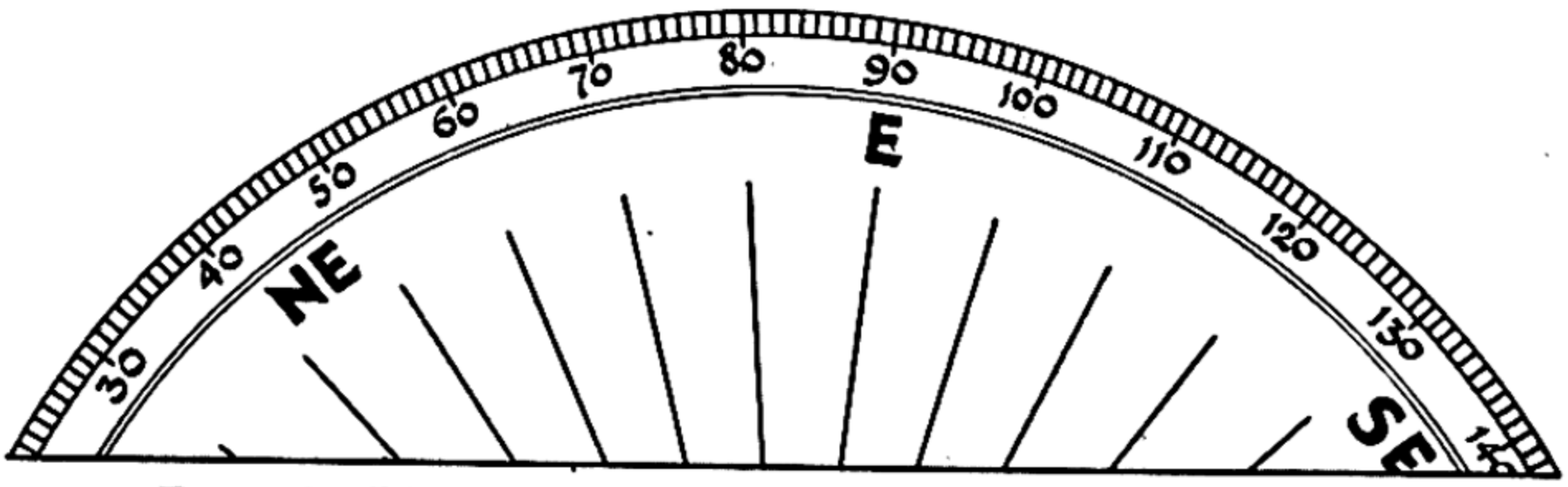


FIG. 176.—PART OF THE DIAL OF THE BOX COMPASS.

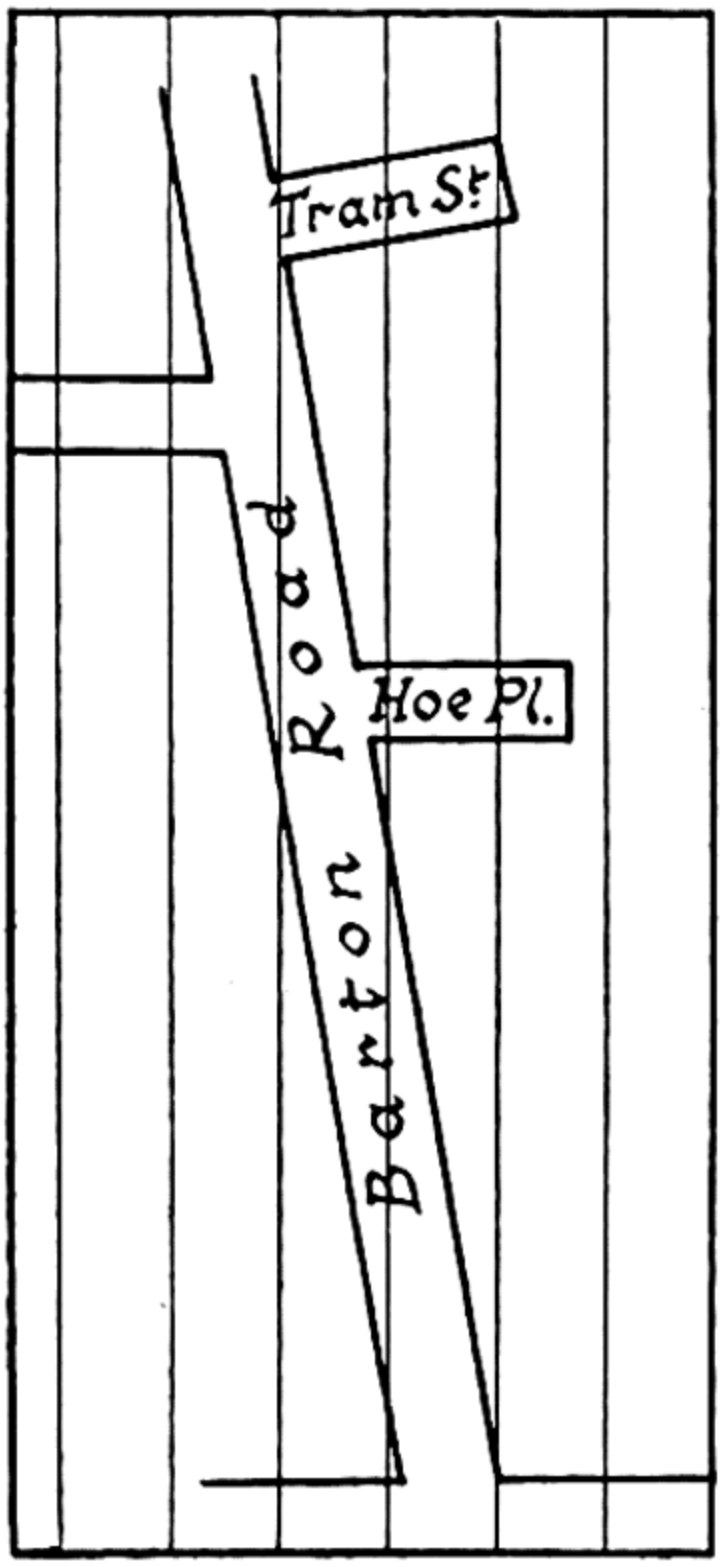


FIG. 177.—MAP 1 DRAWN TO SCALE.

Compare the directions of the streets with the directions on the compass card.

edge at every two degrees, as in the part shown in Fig. 176. The slit for the backsight and the wire for the foresight can be seen. They are trained on to a flagstaff to the east, its direction reading 82°.

THE SURVEY

(See "The Survey" on pp. 175 and 176.)

The method of surveying can be understood from the following example carried out with the home-made compass shown in Fig. 175 and described above. A long straight street was chosen, with three smaller streets running off from it. As there was a good deal of traffic about, the sighting was done along the line of the kerbstone instead of along the middle of the road. One boy looked after the compass, which was stood on a chair, because the tripod was rather shaky; the second went forward to the end of the street as a mark to sight on; the third had a notebook and did the pacing.

The direction of the main street was 350°, that of the side streets 80°, 90°, and 270° respectively (compare Map 1 in Fig. 179 with Fig. 177). A practice map was drawn first on exercise paper, turned so that the lines ran "north-and-south."



[*Photo by E. J. O.*

FIG. 178.—SIGHTING WITH A HOME-MADE BOX COMPASS.

A protractor was of course used for the angles.

B. 1. Using the distances and angles in the notebook, draw Map 1 on a scale of 40 paces to an inch.

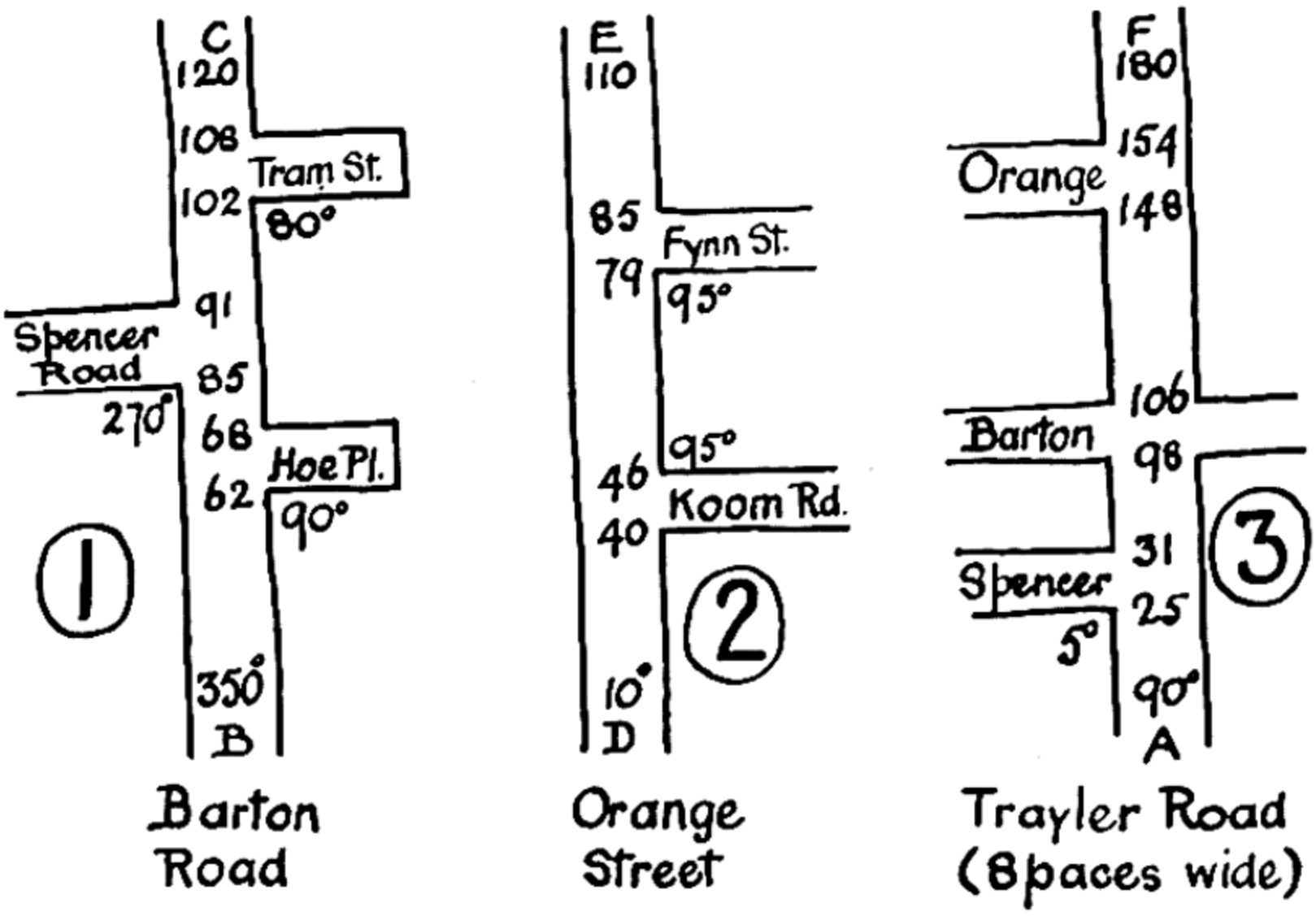


FIG. 179.

B. 2. Draw the maps specified in the notebook as 2 and 3 on the same scale.

C. 1. On page 200 is a rough map of the whole neighbourhood. Draw it to a scale of 50 paces to an inch.

GROUP EXERCISE

Make a compass survey of a number of streets and roads in your neighbourhood (as in Fig. 179), and draw the map to scale.

THE PRISMATIC COMPASS



FIG. 180.—SIMPLE FORM OF PRISMATIC COMPASS.

The prismatic compass is held in the hand close to the eye, the prism in it making it possible for the observer to see the object sighted on and the number of degrees at the same time. The num-

bers cause trouble to beginners because they must be read to the left.

THE PLANE-TABLE

The plane-table, which plays so large a part in surveying, is a drawing-board mounted horizontally on a tripod. The two are held tightly together by means of a screw, but if the screw is loosened somewhat, the board can be turned to any desired position and then fixed by tightening it again.

THE SIGHT-RULE

The Sight-rule or alidade is a boxwood rule with a sight at each end. The backsight has a narrow vertical slit to look



FIG. 181.—SIGHT-RULE.

through ; the foresight has a vertical wire. For convenience in carrying, the two sights are generally hinged, and fold down when not in use into hollows cut in the rule.

WHAT THE PLANE-TABLE SURVEYS

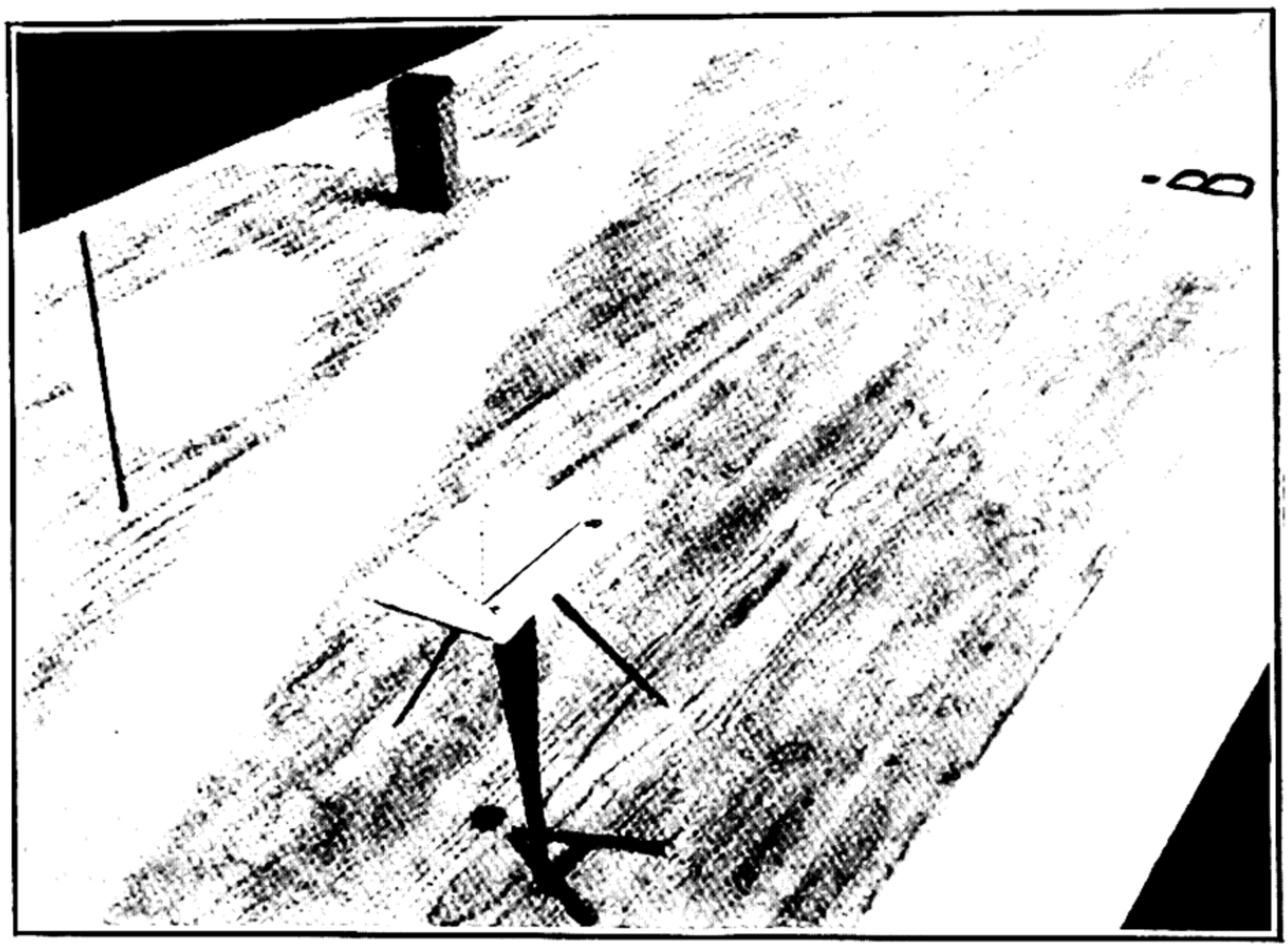
It is most important to realize that with the plane-table we make a survey, not of buildings, roads, and other objects, but of a number of points. In the case of a vertical flagstaff we sight on to the pole and map on the plane-table the point where it enters the ground. If a house is to come on to the map, we choose one angle of it (which is a vertical line corresponding with the flagstaff), and map the point where it touches the ground in the same way.

It will sometimes happen that the point to be surveyed, e.g. where two roads cross in open country, has no vertical

line above it to sight on. In that case someone must be sent to the spot with a ranging pole.

THE SURVEY—FIRST PART

The method of using the plane-table can best be understood by following a simple example. It is required to make a map showing the roads, pond, flagstaff, and tower that appear in the model.



[*Photo by E. J. O.*

FIG. 182.—THE PLANE-TABLE.

1. Rays drawn from A towards the flagstaff and the corner of the tower.

On the ground mark the two ends of a base-line AB.

Choose a suitable scale, and draw the base-line on the plane-table.

Stand the plane-table so that A on the map is vertically over A on the ground (use a plummet for this).

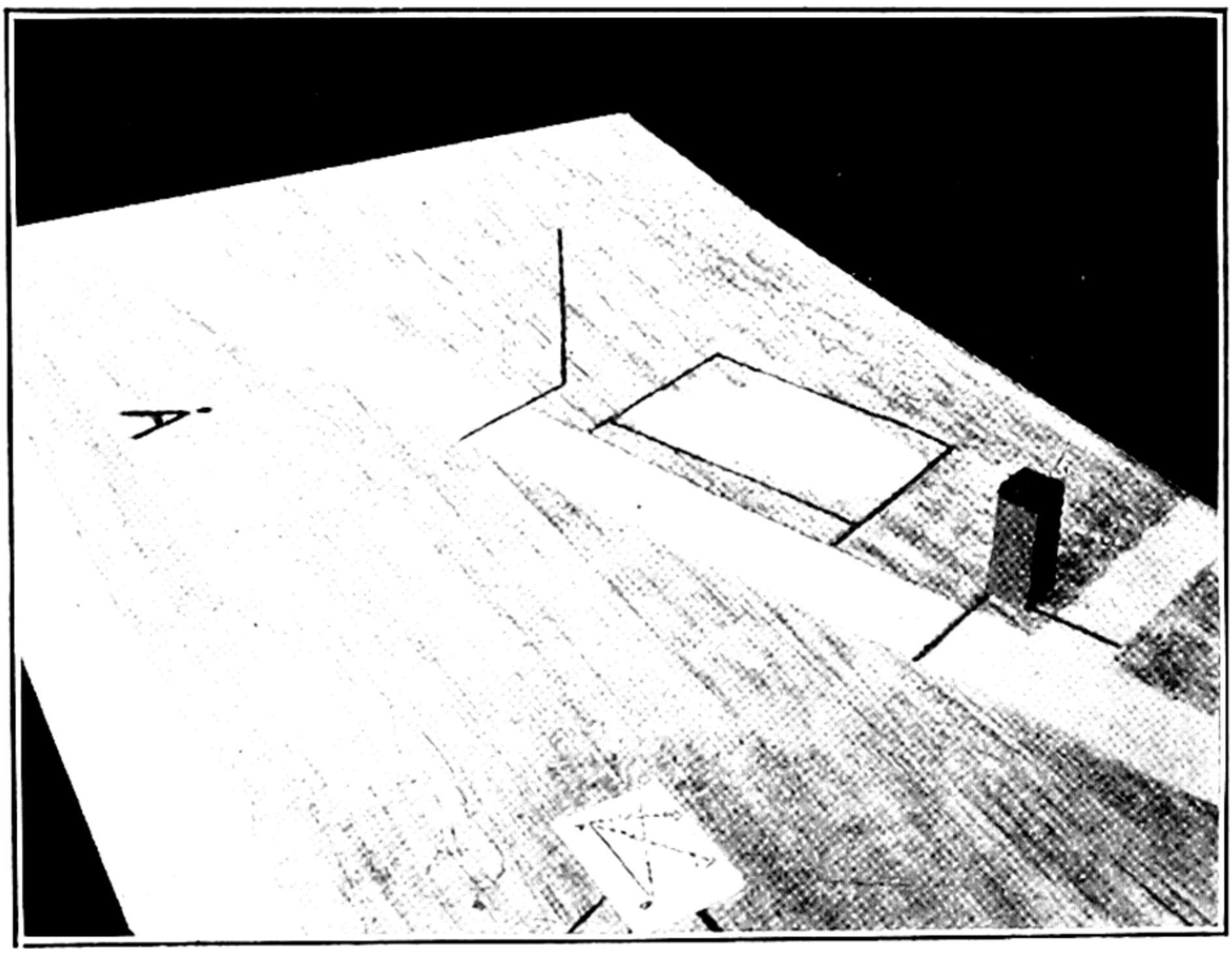
Lay the sight-rule on the map along AB, and turn the board until you sight on a vertical pole held at B.

Tighten the screw to prevent the table turning, and sight

again on B to make sure that the screwing up has not shifted the table.

Lay the rule on the map so that it touches A and sights on the flagstaff. Draw a line and mark it "To Flagstaff."

Shift the rule to touch A and sight on the corner of the tower. Draw a line and mark it "To Tower (S.W. corner)."



[*Photo by E. J. O.*

FIG. 183.—THE PLANE-TABLE.
2. Ray drawn from B towards the flagstaff. 3. Lines marked out for measuring.

Next set the plane-table up at B, sighting back on A to get it correctly oriented. (Fig. 183.)

Sight through B to the flagstaff and draw a line. Where this line crosses the flagstaff line from A is the position of the flagstaff on the map.

Find the position of the corner of the tower in the same way.

THE SURVEY—SECOND PART

On the rough map are the measurements that have been made from the two points surveyed with the plane-table.

In drawing the finished map, it was assumed that the roads met at right angles, and the construction lines were drawn at right angles to the main road or parallel to it.

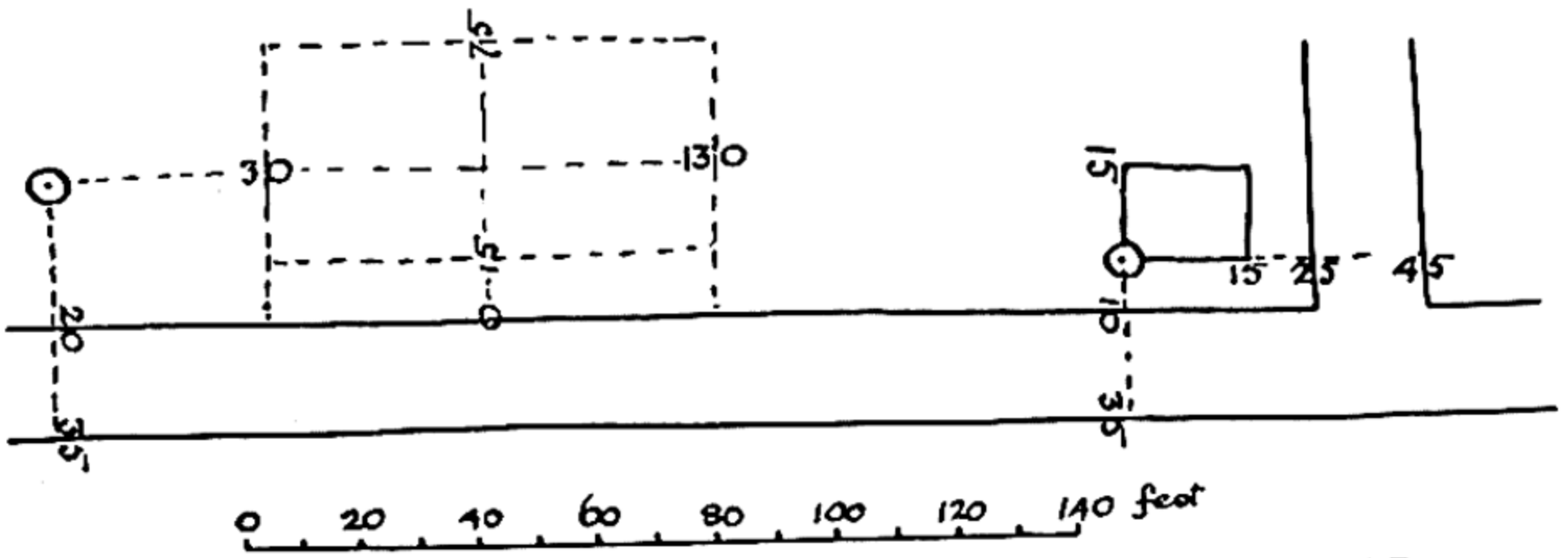


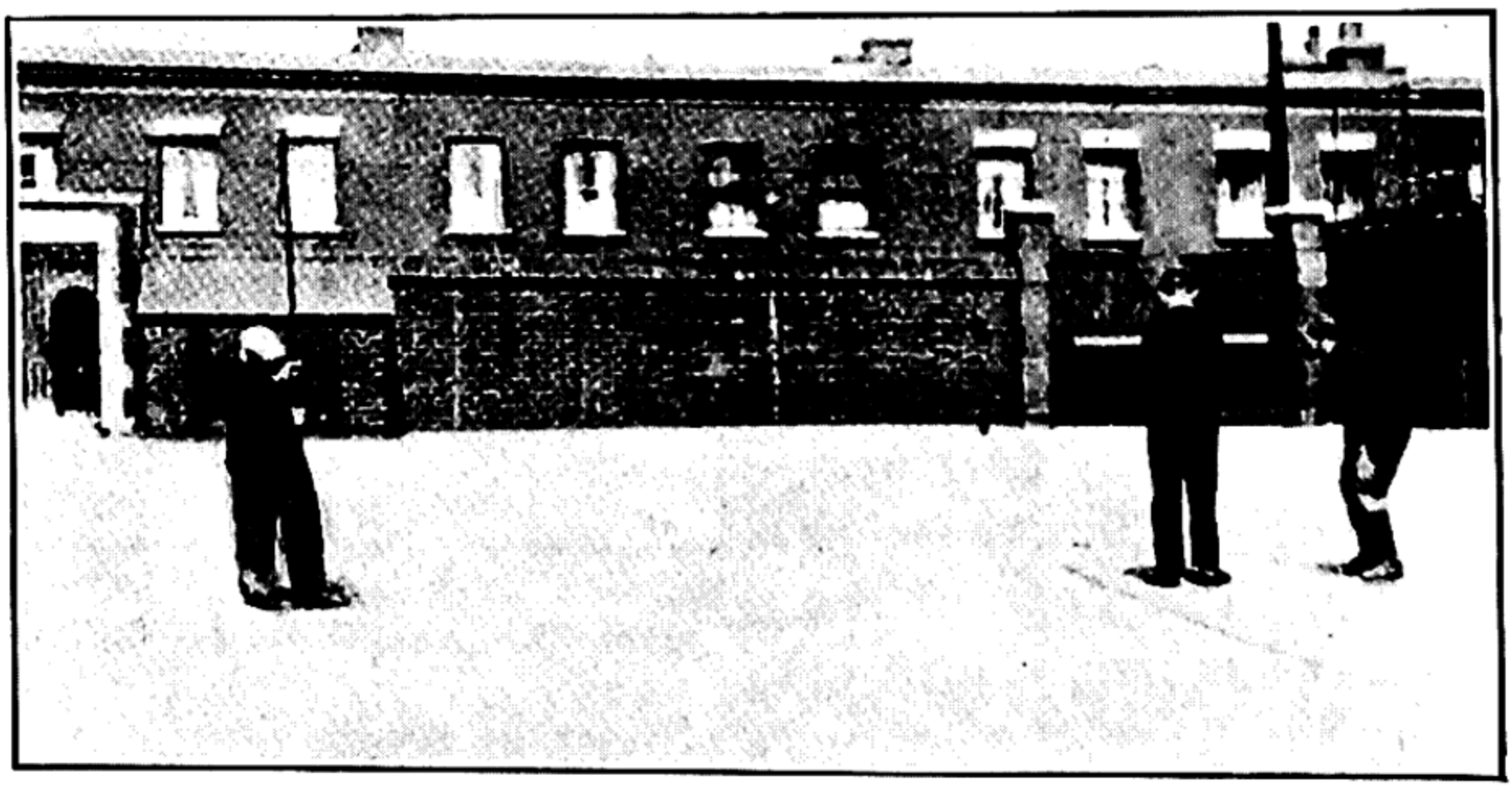
FIG. 184.—MEASUREMENTS FOR COMPLETING THE MAP.

N.B.—The paper used on the plane-table is larger than the board. The edges are folded under and the pins stuck in the underside of the board.

C. 2. From the measurements given in Fig. 184 draw the map to a scale of 60 feet to an inch. The offsets for the pond are given in Fig. 20.

CONTOURING THE PLAYGROUND

The three boys, A, B, and C, in the photograph, are about to draw contour lines in the playground with the sink as the



[*Photo by S. Wyles.*

FIG. 185.—CONTOURING THE PLAYGROUND. FINDING THE HEIGHT OF A "SPOT."

SRINAGAR.
.BI PRATAP COLLEGE LIBRARY,

lowest point. A holds a pole upright on the sink. B holds the sighting-rod level, and C sights along it to the pole. The sights are exactly 4 feet above the ground, and on the pole can be seen a white mark which is also 4 feet above the ground. If the ground were perfectly level, C would sight on to the white mark, but as it slopes he sees a point just above it, and A is moving his finger slowly upward until that point is reached. It proved to be 7 inches above it, showing that the ground where B stands is 7 inches higher than the sink. The spot was marked "7." The heights of a number of other spots were found in the same way, and then contour lines were drawn at intervals of 5, 10, and 15 inches.

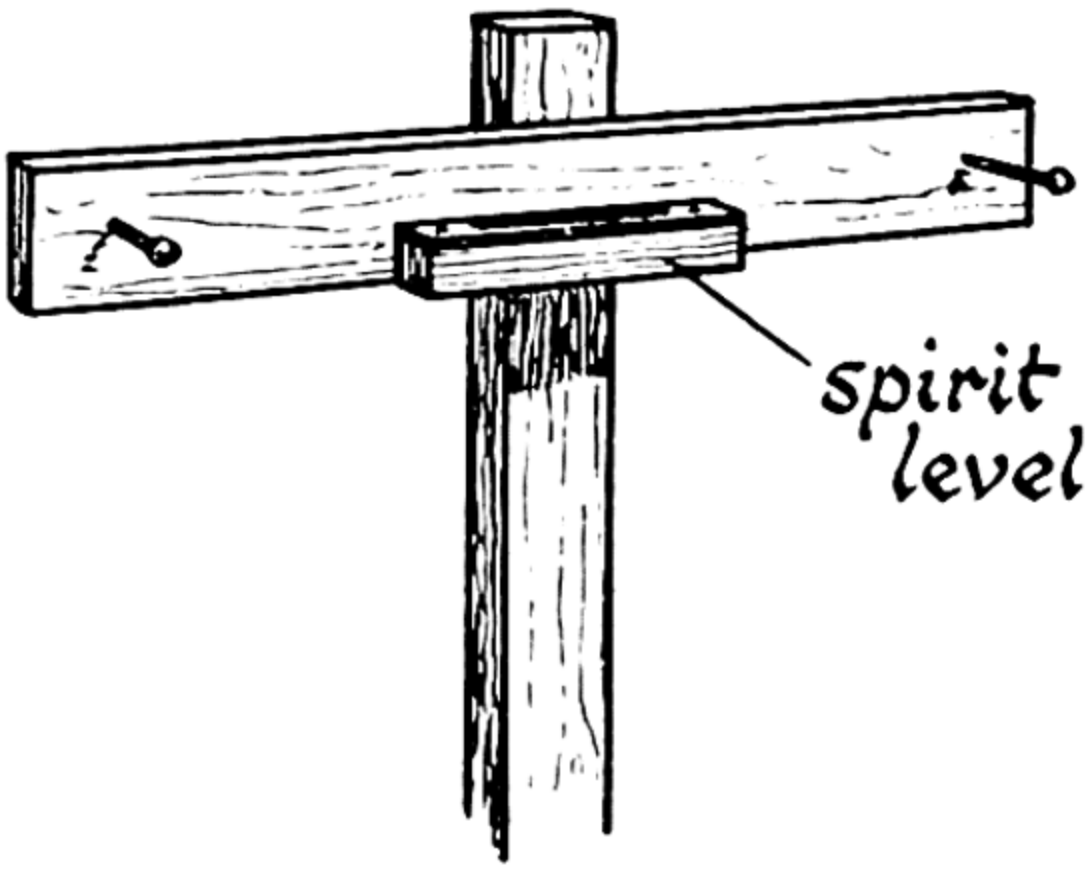


FIG. 186.—SIGHTING ROD.

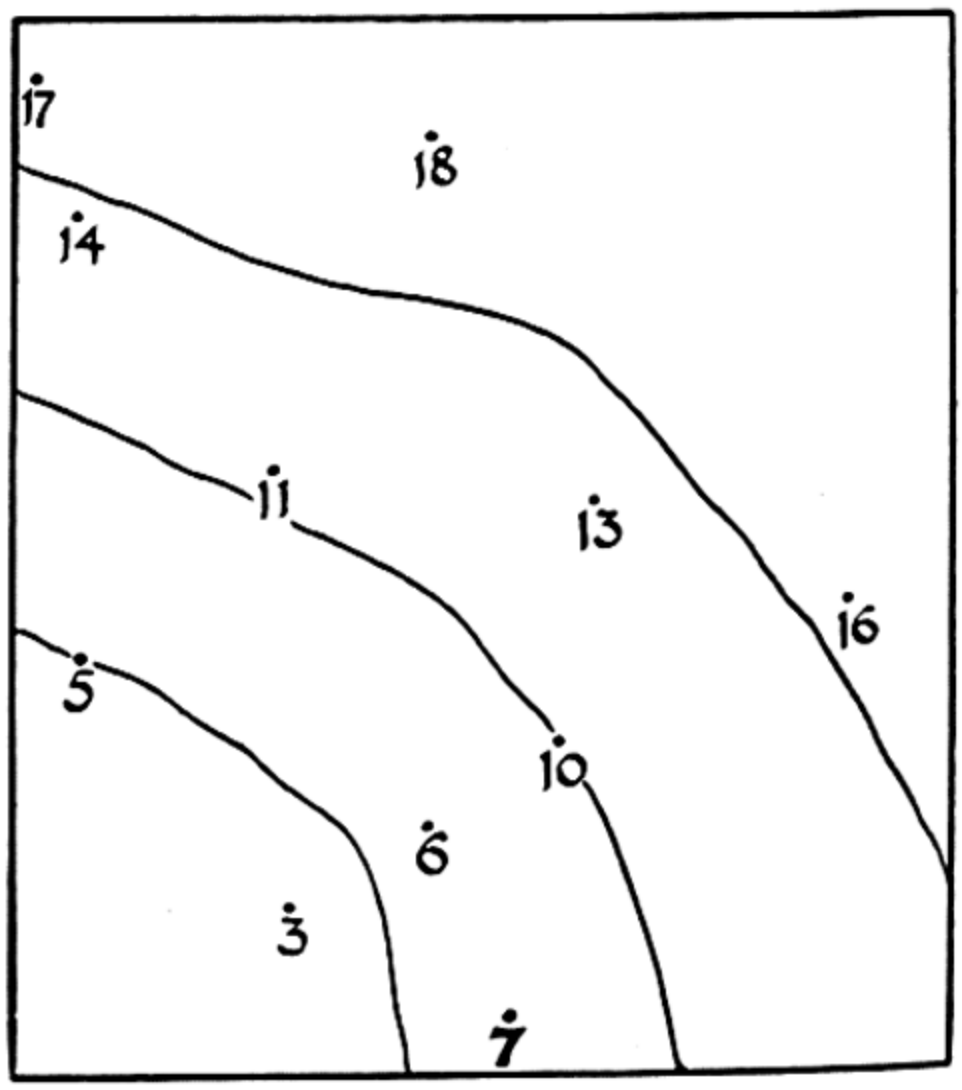
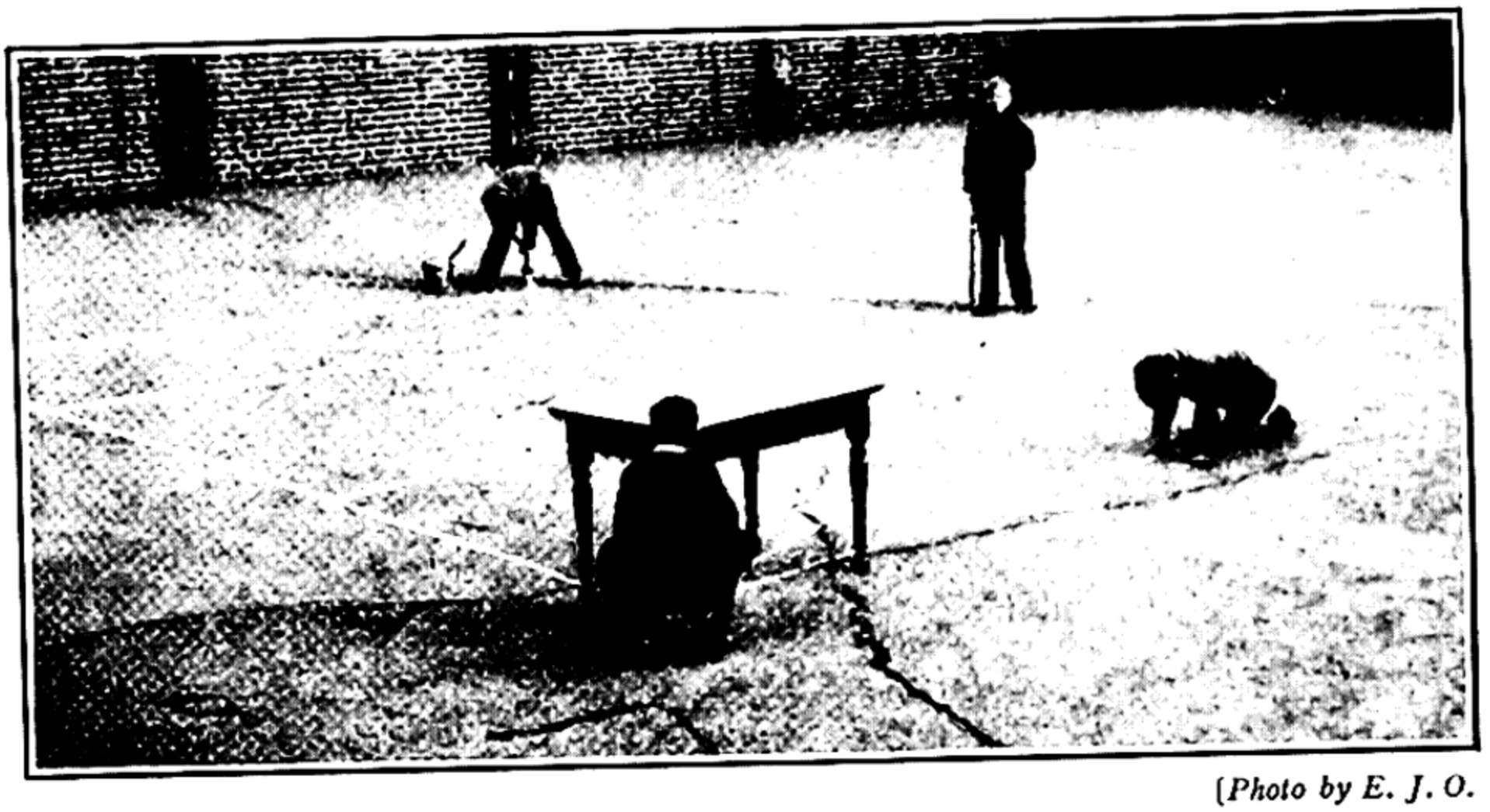


FIG. 187.—CONTOURS DRAWN AT FIVE, TEN, AND FIFTEEN INCHES.

The spots were chosen without any system, and it was therefore impossible to put them on the map correctly without a great deal of trouble. They fell, however, roughly like those in Fig. 187. The slope of the ground, of course, helped in finding the lie of the contours almost as much as the numbers did.

In Fig. 188 a rather different method is being employed.



[*Photo by E. J. O.*

FIG. 188.—CONTOURING THE PLAYGROUND. ANOTHER METHOD.

The table has been levelled with a spirit level by placing pieces of card under some of the legs and on it has been placed a "sighting-box," made out of a tidy-box. The pole has a line on it level with the sights and other lines at 3 inches, 6 inches, and 9 inches below. It was moved along each of the chalk lines radiating from the table until the 3-inch position was found and marked. The five points were then joined up to make the 3-inch contour line. Following this came the 6-inch line, and the 9-inch is now in progress.

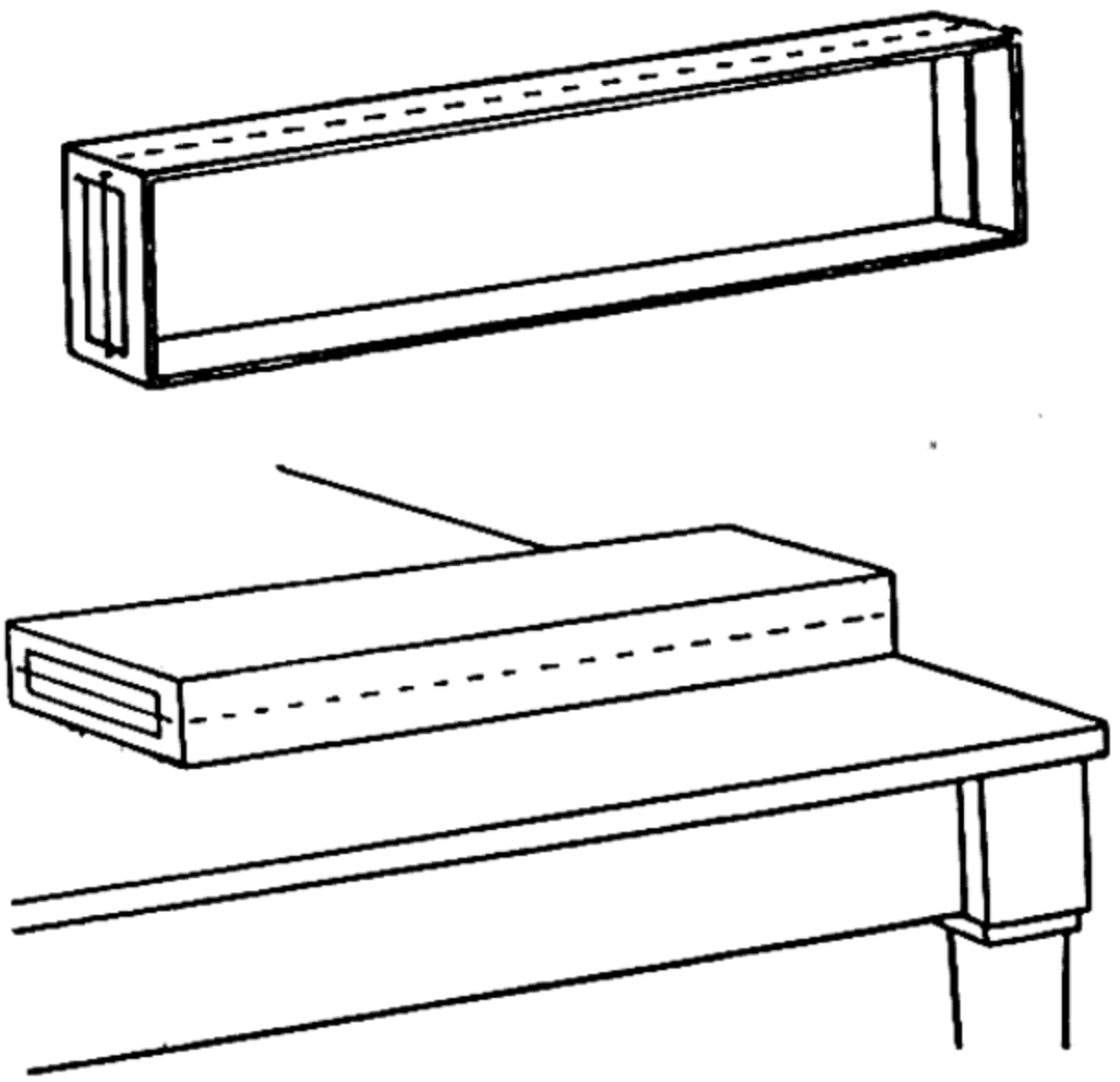


FIG. 189.—A TIDY-BOX WITH FORESIGHT AND BACKSIGHT.

The map was made by measuring the distances of the points from the table along the radiating lines with a chain.

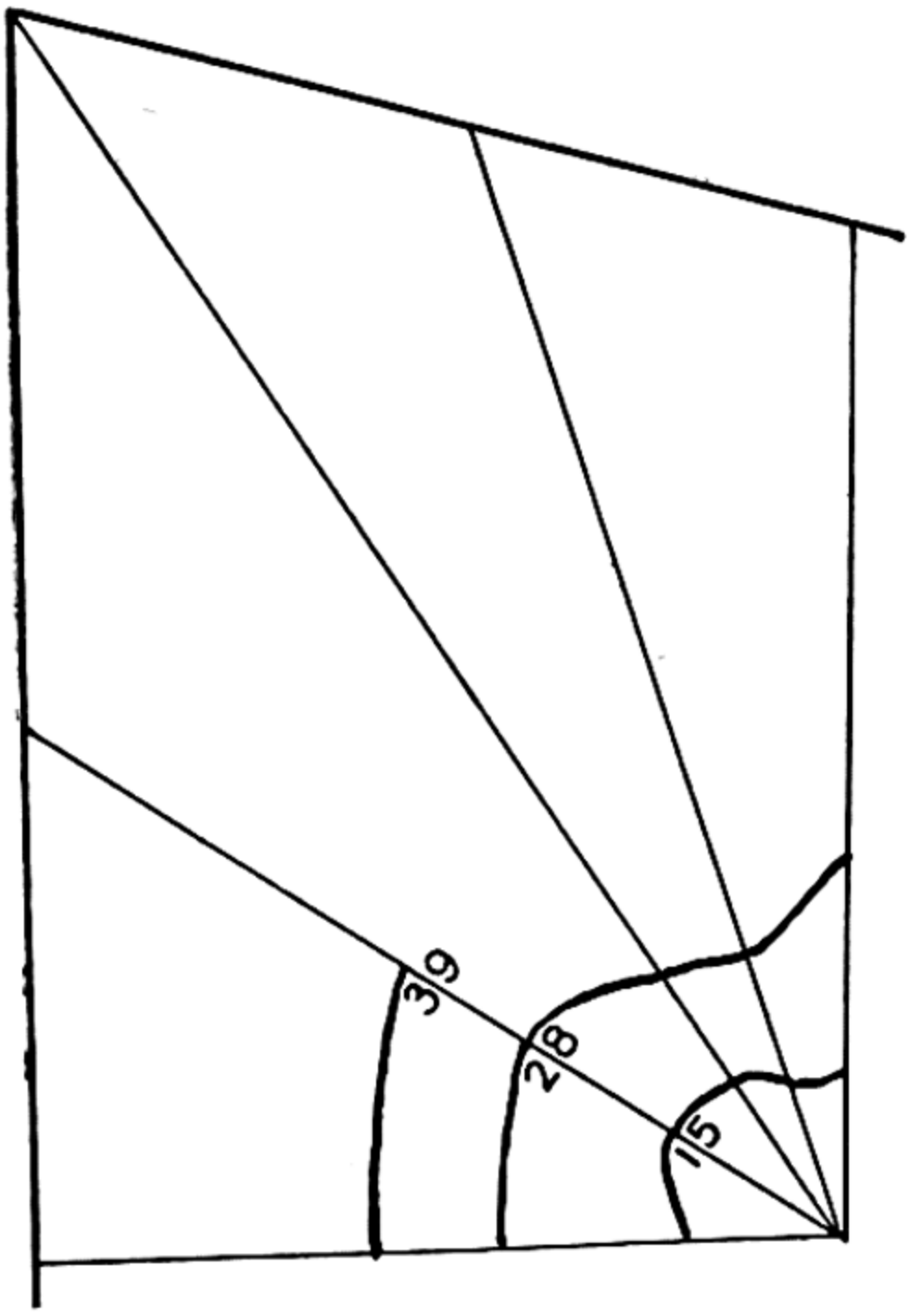


FIG. 190.—MAP OF PLAYGROUND IN Fig. 188. CONTOURS PARTLY DRAWN.

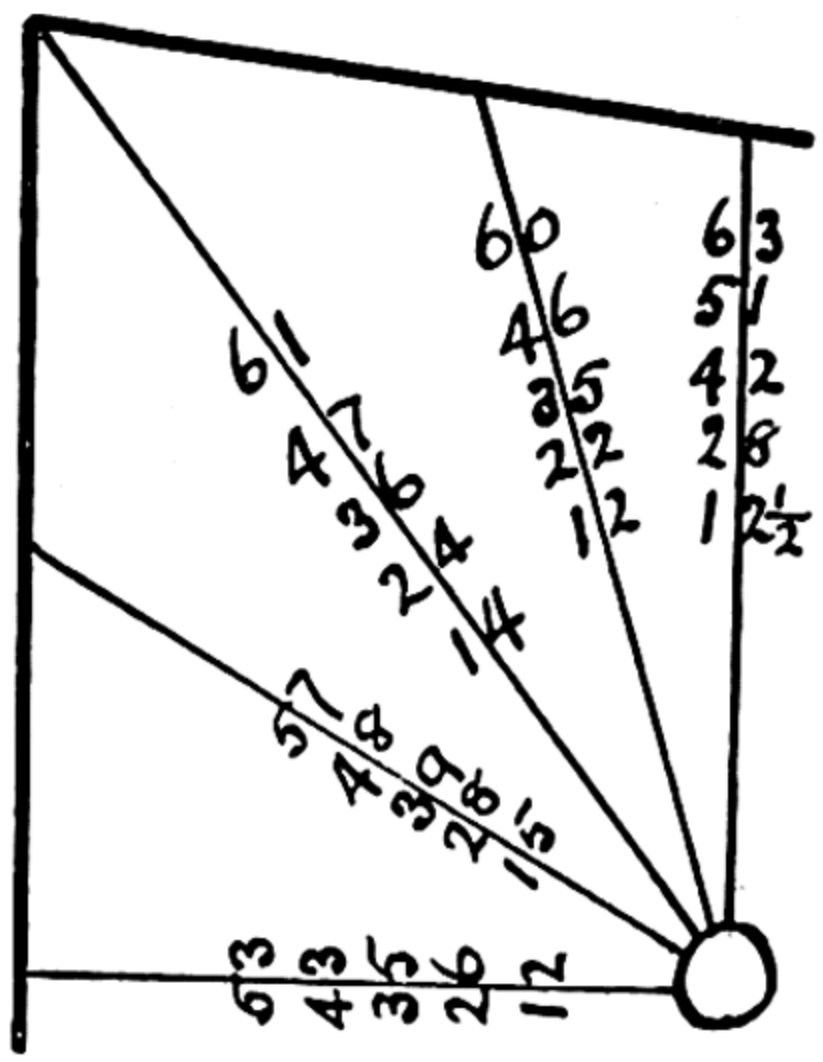


FIG. 191.—ROUGH NOTES FOR THE FULL MAP.

GROUP EXERCISE

Mark out contour lines in your playground like those in Fig. 188. Measure the distances between them along the radiating lines and enter the figures on a rough map. (Fig. 191.)

Draw the contours to scale.

CONTOURING A HILL

A HILL-SLOPE SECTION

The boys in the picture are using the same level for finding the shape of the hill slope as is being used for contouring the playground in Fig. 185. The one on the extreme right moves slowly uphill until the boy who is sighting can see the soles of his boots and signals for him to stop. He is then 4 feet above the spot where the levelling apparatus is standing.



[*Photo by S. Wyles.*

FIG. 192.—MAKING A HILL-SLOPE SECTION.

The distance between the two positions is then measured by the boys with the tape and entered into a notebook. The boy on the extreme left sees that number one keeps a straight line towards the tree at the top of the hill.

This group is A ; three other groups, B, C, D, are working up to the same tree along other lines.

The distances measured by Group A were :

Vertical . .	0	4	8	12	16	20
Along the ground .	0	24	10	36	14	8

These were later marked off on squared paper as in Fig. 193. The side of each square represents 4 feet, making each position one line higher than the position below it.

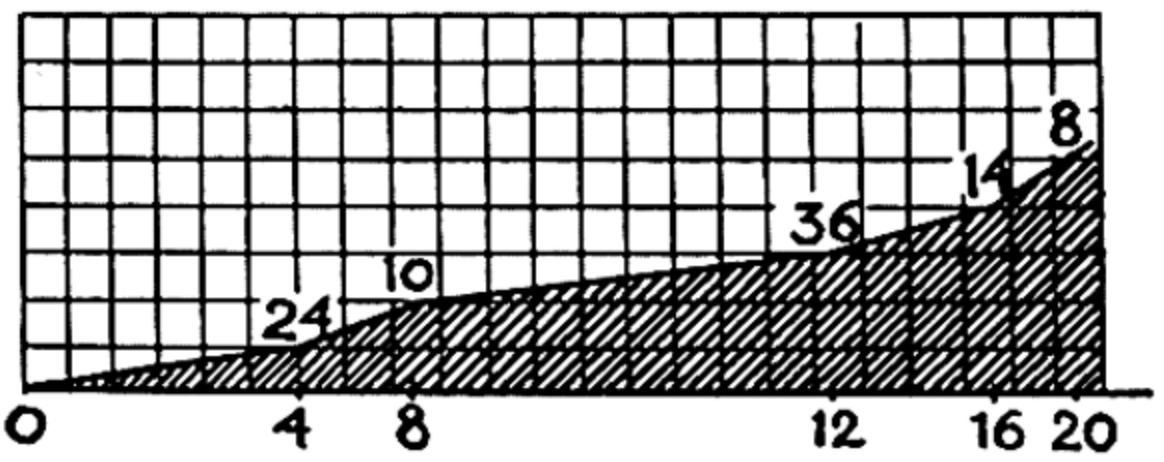


FIG. 193.—THE HILL-SLOPE SECTION (Fig. 192) WORKED OUT.

C. 3. Copy the section thus. Open the compasses 24 feet according to the scale. Put the point at the beginning of the 0 line and mark off the distance on the line above. Open the compasses 10 feet, put the point on the 24 and mark off the distance on the next line above.

Proceed similarly with the other points.

On the map (Fig. 194) the slope is represented by the line AT, T being the top of the hill. The distances along AT are those along the base of the section.

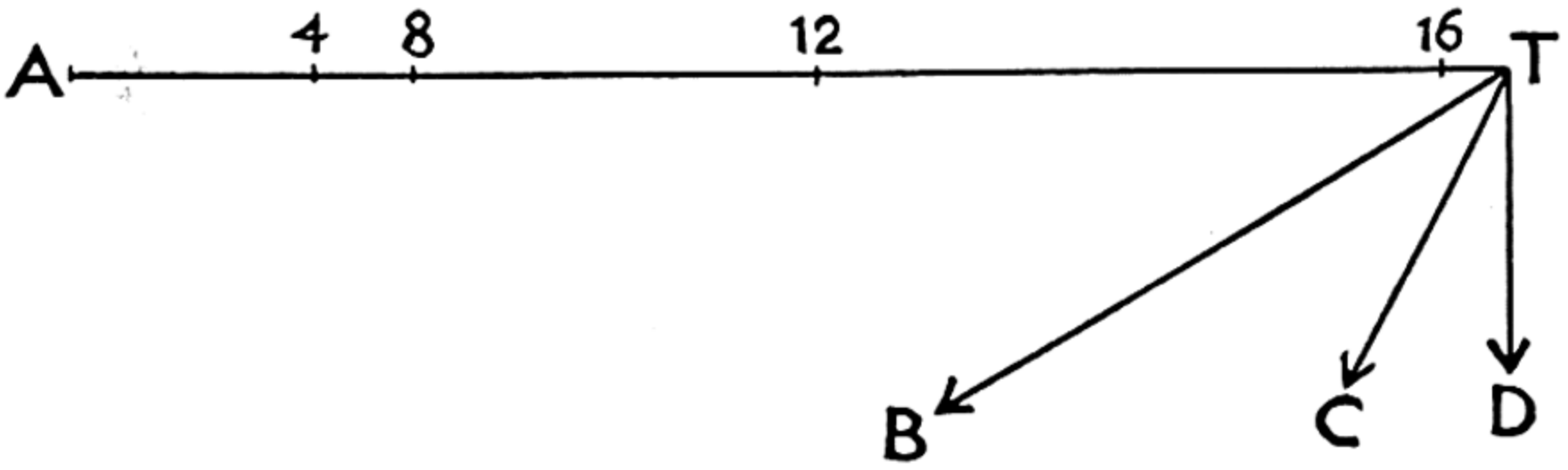


FIG. 194.

C. 4. Draw the following sections (these were measured by the three other groups, B, C, D, working up the hill) :

Vertical	0	4	8	12	16	20
B	0	20	15	38	15	10
C	0	11	11	24	10	7
D	0	19	12	37	13	12

C. 5. Copy the map (Fig. 194) ; mark off the distances along BT, CT, and DT. Draw contour lines at 4 feet, 8 feet, 12 feet, 16 feet.

C. 6. Draw the following sections :

Vertical	0	4	8	12	16	20	24	28
A	0	13	12	15	10	13	17	16
B	0	14	13	16	21	16	16	17
C	0	15	15	15	24	21	15	15
D	0	9	8	12	22	29	49	33

C. 7. Put them on a map like that in Fig. 194, and draw the contours.

In practice it is generally necessary to work downhill, the marker carrying a pole with a mark at 8 feet to be sighted on.

GROUP EXERCISES

1. Draw a section from a neighbouring hill like that in Fig. 193.
2. Draw several sections as in Fig. 194, and add the contour lines.

THE CLINOMETER

The method of drawing contours described above, although easy to understand, can only be used in certain circumstances, the more common method being that in which a clinometer is

used. One form of clinometer consists of a quadrant or semicircle divided into degrees and having a plummet suspended from its centre. When the sights along the top are quite level, the plummet points to 0°; as the instrument is tilted it points to the angle of inclination.

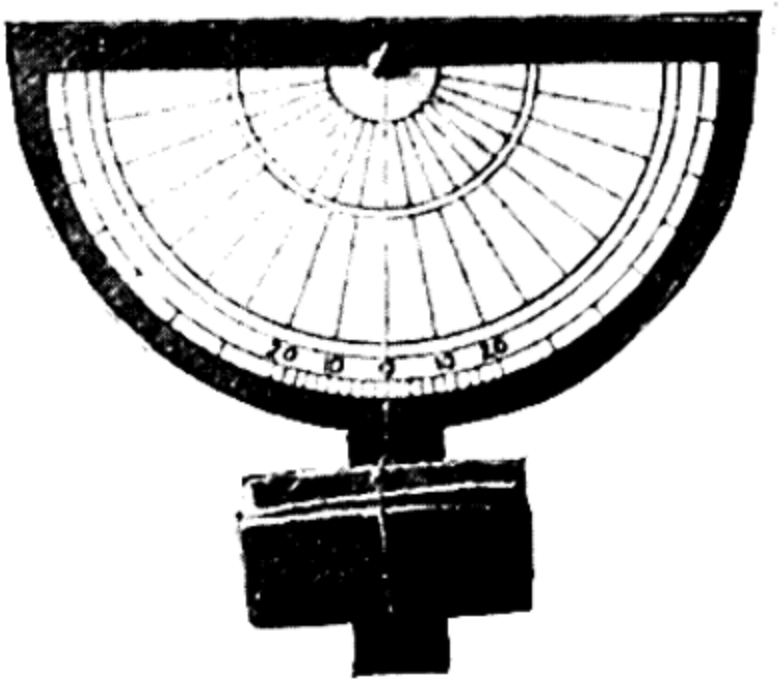


FIG. 195.—A HOME-MADE CLINOMETER.

THE CALCULATION

For converting angular measurements into feet, some very simple calculations are made with the aid of a right-angled triangle.

When the base of the triangle (Fig. 196) is 57 feet and the angle 1°, the perpendicular is 1 foot. If the angle is 2° the perpendicular is 2 feet, and so on up to 11°.

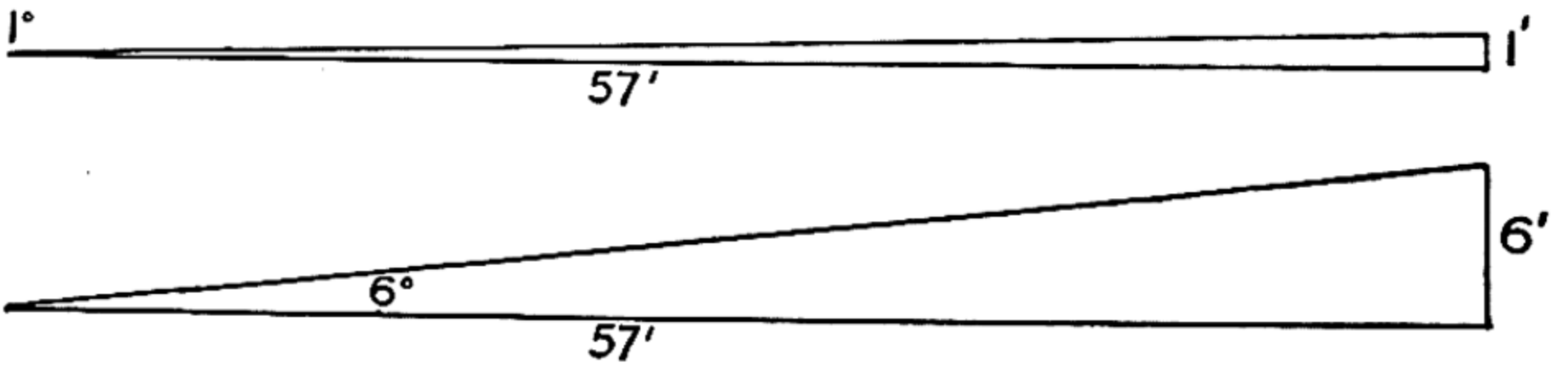


FIG. 196.

C. 8. Draw the triangle with a base of 5·7 inches, and a perpendicular of 1 inch. Test the angle with a protractor.

C. 9. Divide the perpendicular into tenths, and join the points with the other end of the base-line. Test all the angles made with a protractor.

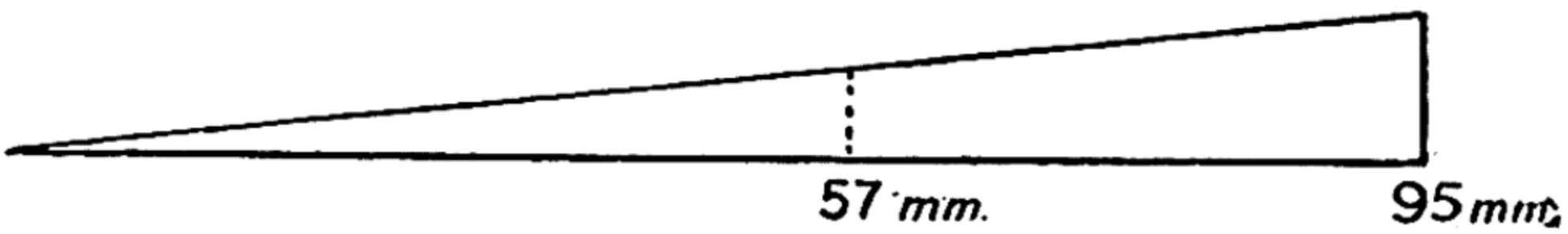


FIG. 197.

In Fig. 197, the base is 95 mm. and the angle 6°.
The perpendicular at the 57 mm. mark is 6 mm.
The one at the 95 mm. mark is $6 \times \frac{95}{57}$ mm. = 10 mm.
Test the diagram with ruler and protractor.

Find the height of the perpendicular in the following cases. In each case use the perpendicular for drawing the triangle and test the angle with a protractor.

C. 10. Angle $4\frac{1}{2}°$; base 9·5 inches.
C. 11. Angle $3\frac{1}{4}°$; base 209 feet.
C. 12. Angle $7\frac{1}{2}°$; base 304 feet.

Using the Clinometer

The hill section in Fig. 198 has two changes of slope as seen by the observer at A, one at A1 and the other at A2. Along the bottom line are the distances as they appear on the map.

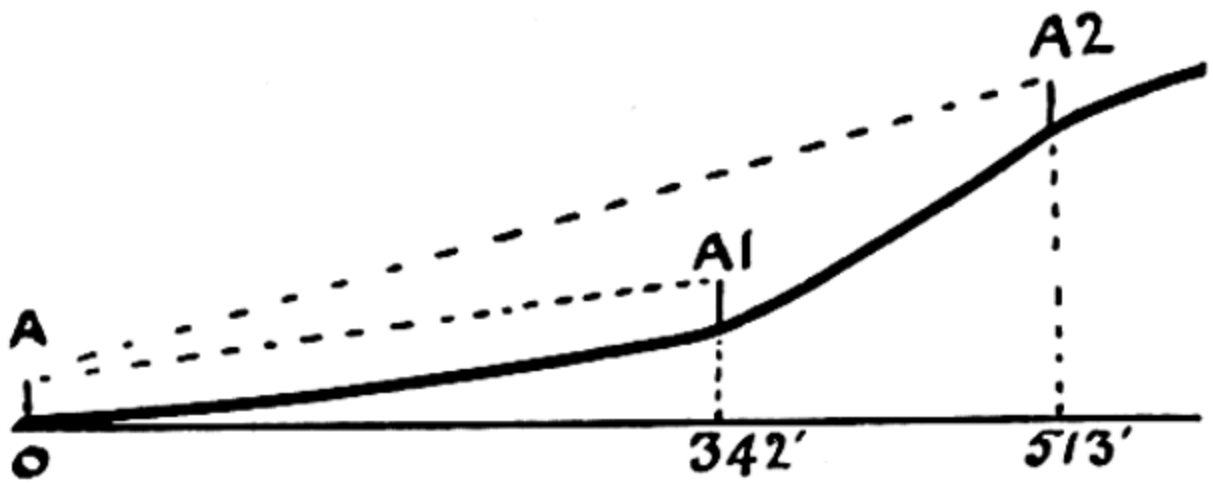


Fig. 198.

The observer sights on a pole held at A1 at his eye-level above the ground and finds the angle is 2°. From this he calculates that A1 is 2 × 2 feet above A.

The inclination of A2 is 10° and its height above A is therefore 3 × 10 feet.

THE THEODOLITE

In the laying out of a network of triangles over a whole country the most important instrument used is the theodolite. It is also used by explorers to find their position on the earth by observing the stars, just as a navigating officer on a ship uses a sextant to observe the position of the sun.

In principle the theodolite is a combination of the angle-meter (Fig. 15) and the clinometer. It is, however, an instrument of very great precision, with scales and verniers so fine that a microscope must be used for reading them.

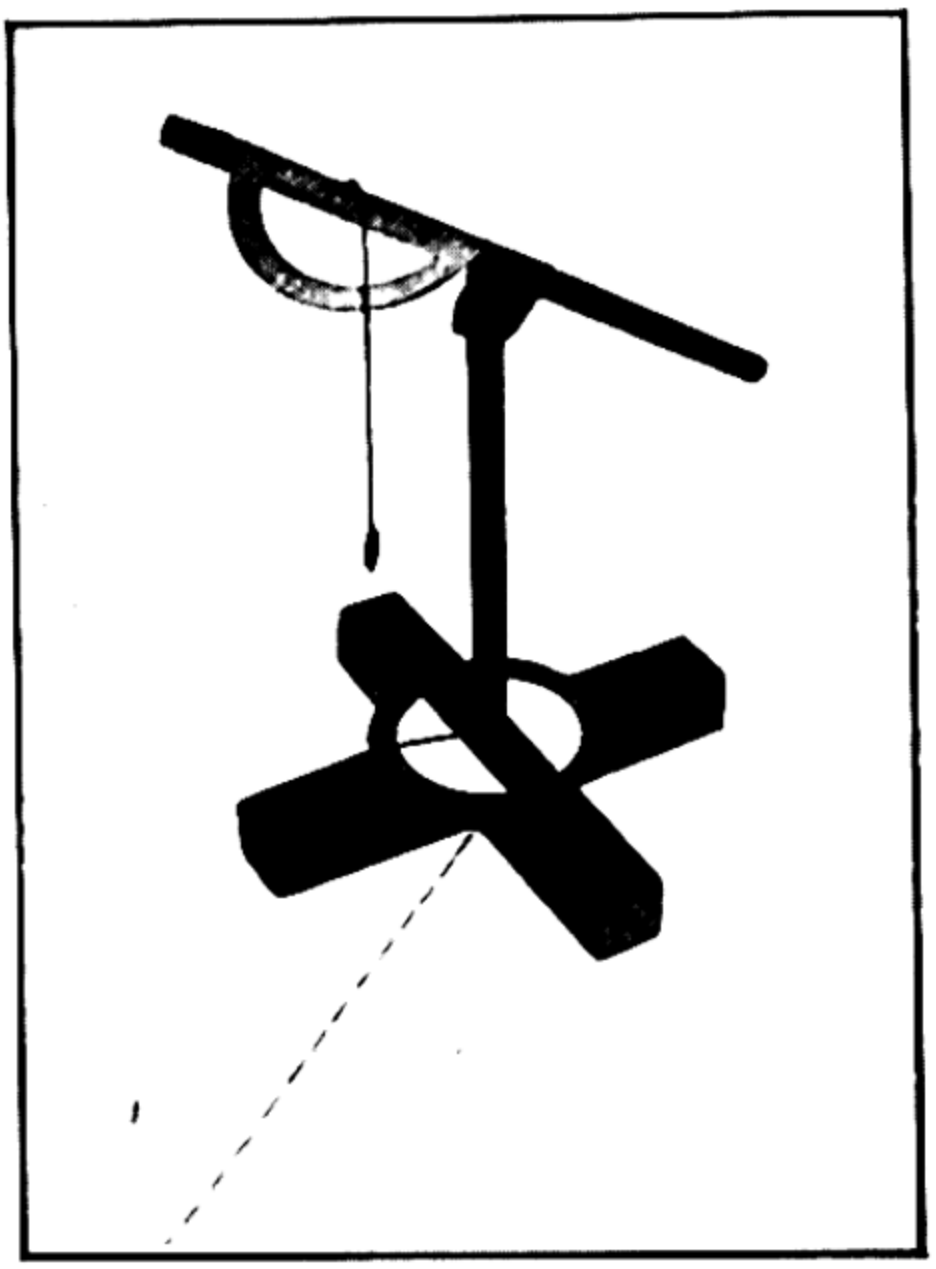


Fig. 199.—A MODEL THEODOLITE.

With the one part

the horizontal angle between two distant points is found (azimuth) and with the other the angular height of a point above the horizon (altitude).

The model in Fig. 200 consists of a tin tube (a pea-shooter !) pivoted on a piece of round wooden rod so that it can see-saw up and down. The rod fits into a round hole in the base, and can be turned to the right or the left. As it turns, the pointer at the bottom marks the degrees on the graduated circle. The amount of tilt is shown by the plummet and semicircular protractor.



[*Model by L. MacFarlane.*

FIG. 200.—A HOME-MADE MODEL OF THE THEODOLITE.

A sight was first taken on a point due south, the direction shown by the dotted line. The tube is now pointing to a star whose azimuth is 70° to the west, the altitude being 30°.

QUESTIONS ON CHAPTER FIFTEEN

C. 1. In surveying, what instruments are used to measure (*a*) horizontal angles and (*b*) vertical angles ?

C. 2. Explain briefly how a survey can be carried out with a prismatic compass.

C. 3. With the aid of a sketch-map explain the use of the plane-table.

C. 4. How would you map the contours on a hill with the aid of a clinometer ?

C. 5. Describe the principle of the theodolite.

TABLES

AVERAGE MONTHLY TEMPERATURES (° F.)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Aberdeen . .	38	38	40	43	47	53	56	56	53	47	42	39
Alexandria . .	57	58	61	65	70	75	78	79	77	74	68	61
Archangel . .	7	9	18	30	41	54	60	57	47	34	22	11
Bergen . .	32	32	36	41	49	56	58	57	54	46	38	36
Berlin . . .	30	33	38	47	57	63	66	65	58	49	39	33
Bombay . .	75	76	80	83	86	84	81	81	81	82	81	77
Breslau . .	29	32	37	46	56	63	65	64	58	48	38	32
Brest . . .	46	46	47	50	55	59	63	63	61	56	50	46
Buluwayo . .	71	70	68	66	61	57	56	62	66	71	71	72
Calcutta . .	65	70	79	85	86	84	83	82	83	80	72	65
Cape Town . .	70	70	68	63	59	56	55	56	52	61	64	68
Cherrapunji . .	53	55	61	64	66	68	69	69	69	66	61	55
Cheyenne . .	26	26	33	41	51	61	67	66	57	45	35	28
Christchurch, N.Z.	62	61	58	53	48	43	42	44	49	53	57	61
Colombo . .	79	80	82	83	83	82	81	81	81	81	80	80
Darwin . .	84	83	84	84	82	79	77	80	83	85	86	85
Denver . .	30	32	39	47	57	67	72	71	62	51	39	32
Falmouth . .	43	43	44	48	52	57	61	60	57	52	48	45
Greenwich . .	39	40	42	47	53	59	63	62	57	50	44	40
Grenada . .	76	76	77	78	79	78	78	79	79	79	78	77
Helwan . .	55	57	63	70	76	80	82	82	78	74	67	58
Hokitika, N.Z. .	61	61	59	55	50	47	45	46	49	52	55	59
Honolulu . .	71	71	71	73	75	77	78	78	78	77	75	72
Khartoum . .	72	75	81	88	92	93	90	88	89	89	82	75
Libreville . .	80	80	81	81	80	78	76	77	78	78	79	79
Manila . .	77	78	80	83	83	82	81	81	80	80	78	77
Moscow . .	12	15	23	38	53	61	66	63	52	40	28	17
Nairobi . .	64	65	65	64	63	62	59	59	62	65	64	62
Orenburg . .	4	8	16	25	59	67	72	67	55	40	24	12
Para . . .	78	77	78	78	78	79	78	78	78	79	80	79
Perth, W.A. .	74	74	71	66	60	56	55	56	58	61	65	71
Quito . . .	55	55	55	55	55	55	55	55	55	55	55	55
Rome . . .	44	47	51	57	64	71	77	76	70	62	52	46
St. Helena . .	63	65	66	65	63	60	58	57	57	58	59	61
St. Louis, U.S.A. .	30	35	43	56	66	75	79	77	70	57	44	36
St. Lucia, W.I. .	76	76	77	79	80	81	81	81	80	79	78	77
Shanghai . .	38	39	46	56	65	73	80	80	73	63	52	42
Singapore . .	79	81	81	82	82	81	81	81	81	81	81	79
Stockholm . .	27	26	29	38	47	57	62	60	53	43	35	28
Utrecht . .	35	37	41	49	57	63	65	65	59	51	42	37
Valentia Island .	45	45	45	48	52	56	59	59	56	52	47	45
Vancouver . .	36	38	42	47	54	59	63	62	56	49	43	38
Vladivostock .	6	14	27	40	49	57	65	69	62	49	30	14
Warsaw . .	26	29	35	46	57	63	66	63	56	46	36	30
Wellington, N.Z. .	63	63	61	58	53	50	48	49	52	54	57	60
Winnipeg . .	3	1	15	39	51	62	66	63	54	42	25	7
Yarmouth . .	38	39	41	45	51	57	61	60	57	50	44	39
York . . .	38	39	42	46	52	58	61	60	56	49	43	39

AVERAGE MONTHLY RAINFALL (INCHES)

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Aberdeen . .	2·1	2·1	2·4	2·0	2·3	1·9	2·9	2·9	2·5	3·0	3·2	3·2
Alexandria .	2·1	0·9	0·6	0·1	—	—	—	—	—	0·2	1·4	2·6
Archangel .	0·8	0·7	0·8	0·7	1·0	1·5	2·2	2·1	2·0	1·5	1·1	0·8
Bergen . .	5·9	6·5	3·5	3·4	3·4	4·3	5·1	7·2	8·1	8·7	6·7	8·0
Berlin . .	1·7	1·4	1·6	1·5	1·9	2·4	3·0	2·3	1·7	1·7	1·7	1·9
Bombay . .	0·1	0·1	—	—	0·7	19·9	24·2	14·6	10·6	1·9	0·4	0·1
Breslau . .	1·3	1·2	1·5	1·6	2·3	2·5	3·2	2·9	1·9	1·5	1·5	1·5
Brest . .	5·7	3·8	2·5	2·9	2·5	2·8	1·7	2·3	2·4	4·2	6·1	5·1
Buluwayo .	5·9	3·1	2·8	0·8	0·2	0·1	—	0·1	0·3	1·0	4·3	5·1
Calcutta . .	0·4	1·1	1·3	1·7	5·7	11·4	12·9	12·2	10·4	3·9	0·6	0·2
Cape Town .	0·7	0·6	0·9	1·9	3·8	4·5	3·6	3·4	2·3	1·6	1·1	0·8
Cherrapunji .	0·7	2·3	10·6	31·3	50·8	103·6	107·5	81·5	49·4	16·8	2·3	0·3
Cheyenne . .	0·4	0·6	0·9	1·8	2·4	1·5	2·0	1·5	1·2	0·8	0·5	0·5
Christchurch, N.Z.	2·2	1·7	2·4	2·0	2·3	2·4	2·9	2·0	2·0	1·6	2·0	2·1
Colombo . .	3·2	1·9	4·3	9·7	10·9	7·3	4·4	3·2	4·8	13·4	11·8	5·1
Darwin . .	15·3	13·0	9·7	4·5	0·7	0·2	0·1	0·1	0·5	2·1	5·2	10·3
Denver . .	0·4	0·5	1·0	2·1	2·4	1·4	1·8	1·4	1·0	1·0	0·6	0·7
Falmouth .	4·2	3·7	3·5	2·6	2·2	2·3	2·8	3·2	2·9	5·0	4·8	6·3
Greenwich .	1·9	1·5	1·6	1·6	1·9	2·0	2·4	2·3	2·1	2·7	2·2	2·0
Grenada . .	4·4	2·8	2·7	2·2	4·2	8·2	9·4	9·3	8·0	7·8	8·5	7·2
Helwan . .	—	—	—	—	—	—	—	—	—	—	—	—
Hokitika, N.Z. .	10·0	7·4	9·7	9·2	9·8	9·8	9·1	9·2	9·3	11·7	10·6	10·4
Honolulu . .	3·7	4·3	3·8	2·3	1·9	1·1	1·3	1·5	1·5	1·1	4·2	4·2
Khartoum .	—	—	—	—	0·1	0·3	1·8	2·6	0·7	0·2	—	—
Libreville . .	10·5	10·4	13·8	13·0	9·6	0·7	—	0·8	3·9	11·3	14·6	8·6
Manila . .	0·9	0·4	0·8	1·3	4·4	9·3	17·3	16·0	14·3	6·7	5·2	3·1
Moscow . .	1·1	0·9	1·2	1·5	1·9	2·0	2·8	2·9	2·2	1·4	1·6	1·5
Nairobi . .	1·9	4·2	3·7	8·3	5·2	2·0	0·8	0·9	0·9	2·0	5·8	3·5
Orenburg . .	1·2	0·7	0·9	0·8	1·3	1·6	1·4	1·3	1·0	1·2	1·4	1·4
Para . .	13	14	14	13	10	6	5	5	4	3	2	6
Perth, W.A. .	0·3	0·3	0·7	1·7	4·9	6·6	6·4	5·6	3·3	2·1	0·8	0·6
Quito . .	4·2	4·4	5·3	7·5	5·1	1·5	0·9	1·5	3·0	3·7	3·8	3·8
Rome . .	3·1	2·4	2·7	2·6	2·2	1·5	0·7	1·1	2·9	4·5	4·9	3·6
St. Helena .	3·0	3·8	4·9	3·9	4·2	4·1	4·0	3·7	3·0	1·9	1·7	2·0
St. Louis, U.S.A.	2·2	2·7	3·4	3·7	4·7	5·0	3·8	3·5	3·1	2·8	3·1	2·8
St. Lucia, W.I. .	5·3	3·6	3·8	3·4	5·9	8·6	9·3	10·6	9·9	9·3	9·1	7·8
Shanghai . .	2·1	2·3	3·5	3·8	3·5	7·2	5·9	5·7	4·5	3·4	2·0	1·2
Singapore .	9·9	6·6	7·4	7·6	6·7	6·9	6·8	8·0	6·8	8·1	9·9	10·6
Stockholm .	0·8	0·7	0·8	0·9	1·4	1·7	2·3	2·4	1·8	2·0	1·4	1·1
Utrecht . .	2·1	1·7	2·0	1·7	2·0	2·3	3·0	3·3	2·6	2·9	2·4	2·7
Valentia Island .	5·9	5·1	4·4	3·8	3·2	3·5	3·9	4·8	4·5	5·9	5·4	6·5
Vancouver .	8·6	6·1	5·3	3·3	3·0	2·7	1·4	1·8	4·1	5·9	10·0	7·8
Vladivostock .	0·3	0·3	0·6	1·3	2·0	2·8	3·2	4·3	4·3	1·8	1·1	0·4
Warsaw . .	1·3	1·0	1·3	1·6	2·0	2·4	3·4	2·6	1·8	1·6	1·4	1·4
Wellington, N.Z.	2·7	2·5	2·8	3·2	4·0	4·0	4·6	3·8	3·2	3·4	3·0	2·7
Winnipeg . .	0·9	0·8	1·3	1·6	2·2	3·3	3·2	2·2	1·9	1·4	1·0	0·9
Yarmouth .	1·7	1·5	1·8	1·5	1·7	1·8	2·3	2·5	2·0	2·9	2·4	2·4
York . .	1·8	1·5	1·7	1·6	2·0	2·1	2·5	2·5	1·6	2·7	2·1	2·2

BOMBAY

	January 1931.				July 1931.			
	Max.	Min.	Rain.	Wind.	Max.	Min.	Rain.	Wind.
1	93	72	—	E.N.E.	84	73	2·0	S.
2	94	72	—	E.N.E.	85	75	3·1	W.
3	93	71	—	E.N.E.	85	73	1·9	W.
4	91	70	—	E.S.E.	88	77	1·2	W.N.W.
5	91	70	—	E.N.E.	86	76	0·9	N.N.W.
6	91	71	—	E.N.E.	84	74	1·0	S.W.
7	93	73	—	E.S.E.	87	75	1·0	E.S.E.
8	87	72	—	N.N.E.	89	78	0·1	W.
9	85	70	—	N.N.E.	89	77	0·4	W.S.W.
10	86	71	—	N.N.E.	88	77	1·2	W.S.W.
11	82	68	—	N.N.E.	85	74	0·8	N.N.W.
12	86	67	—	E.N.E.	86	75	0·9	W.S.W.
13	87	67	—	N.E.	89	78	0·4	W.N.W.
14	88	68	—	E.	88	77	1·1	W.N.W.
15	90	69	—	E.	84	73	6·5	W.S.W.
16	90	68	—	N.N.E.	82	75	6·2	W.
17	89	69	—	N.E.	84	75	1·0	W.N.W.
18	90	69	—	E.N.E.	85	76	0·9	W.S.W.
19	88	69	—	N.E.	87	75	1·0	W.S.W.
20	90	69	—	N.E.	85	77	1·0	W.N.W.
21	90	69	—	N.	87	77	0·9	S.W.
22	84	69	—	E.N.E.	84	76	0·9	W.S.W.
23	85	67	—	N.N.E.	85	79	0·8	N.N.W.
24	83	69	—	E.S.E.	88	79	0·1	N.W.
25	83	68	—	E.N.E.	88	79	0·1	N.W.
26	83	67	—	N.N.E.	82	75	4·7	S.W.
27	84	66	—	E.N.E.	83	76	0·7	S.
28	86	58	—	E.N.E.	85	70	0·1	W.S.W.
29	84	67	—	E.N.E.	87	79	0·7	W.
30	82	67	—	E.N.E.	81	75	6·7	W.N.W.
31	81	63	—	E.N.E.	84	75	1·7	W.S.W.

AVERAGE NUMBER OF DAYS OF RAIN

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Para . .	27	26	28	26	23	21	19	16	15	13	10	19
Libreville .	12	14	17	16	11	3	0	5	11	19	18	10
Brest . .	23	16	13	16	16	11	12	15	10	18	24	22
Bergen .	21	19	17	16	16	16	16	20	19	20	20	22
Perth, W.A.	3	3	5	7	14	17	17	18	15	12	6	4
Greenwich .	15	14	15	12	13	11	13	13	11	15	15	6
Colon . .	16	14	12	15	21	24	25	25	23	24	25	22
Manila .	5	4	4	4	11	15	23	23	22	19	14	12
Shanghai .	10	10	13	13	12	14	11	11	12	10	8	7
St. Lucia .	21	18	18	15	18	24	26	25	21	22	21	23
Wellington .	10	9	11	13	17	17	18	17	15	14	13	12
Grenada .	20	16	15	13	17	23	25	23	20	19	21	21

GREENWICH

	January 1932.				July 1932.			
	Max.	Min.	Rain.	Wind.	Max.	Min.	Rain.	Wind.
1	50	21	0·03	S.S.W.	76	56	0·43	S.W.
2	54	50	0·03	W.S.W.	73	52	—	W.S.W.
3	56	52	—	W.S.W.	72	47	—	S.S.W.
4	52	48	—	S.W.	81	53	—	S.S.W.
5	52	46	0·04	S.W.	68	56	0·17	W.
6	60	46	0·56	S.W.	76	54	—	W.S.W.
7	47	39	0·02	S.W.	75	52	0·14	S.W.
8	41	29	—	O.	82	53	—	W.S.W.
9	48	27	—	S.S.W.	84	58	—	W.S.W.
10	49	44	0·36	S.S.W.	88	59	—	S.S.E.
11	51	40	0·14	S.S.W.	82	58	0·56	E.
12	49	35	0·06	S.S.W.	78	61	—	W.N.W.
13	55	43	—	S.S.W.	77	57	—	S.
14	50	36	—	S.S.W.	79	53	—	S.W.
15	53	45	0·02	S.S.W.	62	57	—	N.
16	52	49	—	S.S.W.	77	53	—	N.
17	53	46	0·09	W.S.W.	66	50	0·03	N.
18	53	49	—	S.W.	59	49	0·11	N.
19	54	47	—	S.W.	74	46	—	N.W.
20	52	35	—	O.	77	52	—	W.S.W.
21	51	30	—	S.	72	54	—	N.N.W.
22	48	34	0·01	S.W.	72	53	0·34	W.S.W.
23	49	37	—	S.S.E.	68	50	—	N.N.W.
24	39	29	—	S.S.E.	66	50	0·12	S.S.W.
25	43	28	—	O.	64	53	1·01	S.S.W.
26	47	38	—	N.E.	70	52	0·22	S.W.
27	41	39	—	E.	71	54	0·14	S.W.
28	36	32	—	S.W.	67	54	0·06	W.S.W.
29	41	34	—	S.W.	74	60	0·01	W.S.W.
30	47	33	—	N.	79	56	—	S.W.
31	47	33	—	N.E.	73	54	0·03	S.W.

PRESSURE AT DIFFERENT HEIGHTS

Kilometres.	Feet.	Millibars.
0	0	1014
1	3,300	900
2	6,600	795
3	9,800	699
4	13,100	615
5	16,400	638
6	19,700	469
7	23,000	407
8	26,200	352
9	29,500	303
10	32,800	261

PRESSURES

Inches.	Millimetres.	Millibars.
1	25·4	33·9
0·0394	1	1·33
0·0295	0·75	1

On the Australian Weather Chart on page 106 the isobars are numbered both in millibars and inches.

WEATHER OBSERVATIONS

VANCOUVER, 1931

	January.			July.		
	Temperature.		Rain.	Temperature.		Rain.
	Max.	Min.		Max.	Min.	
1	43	39	0·15	73	47	—
2	46	41	0·48	76	51	—
3	44	38	0·01	76	51	—
4	46	43	0·58	79	53	—
5	43	41	0·78	74	55	—
6	43	38	0·01	83	52	—
7	46	38	0·12	88	56	—
8	42	38	0·06	85	58	—
9	43	40	0·41	77	60	—
10	45	41	0·18	76	58	0·01
11	46	42	0·61	69	53	—
12	48	42	—	64	53	0·37
13	47	44	0·27	66	55	0·04
14	47	38	0·79	72	52	0·02
15	43	35	0·14	74	50	—
16	45	40	0·39	75	51	—
17	46	41	0·02	80	59	—
18	45	30	—	78	54	—
19	46	29	—	81	55	—
20	53	39	0·04	90	58	—
21	47	35	0·04	77	57	—
22	53	43	1·86	76	52	—
23	47	44	0·96	79	54	—
24	50	38	0·06	82	52	—
25	47	39	0·55	78	50	—
26	50	44	0·51	76	50	—
27	50	44	1·71	74	52	—
28	58	48	·15	74	56	—
29	55	42	—	80	57	—
30	43	36	0·02	77	54	—
31	49	33	0·02	79	54	—

WINNIPEG, 1931

	January.			July.		
	Temperature.		Rain.	Temperature.		Rain.
	Max.	Min.		Max.	Min.	
1	15	2	—	85	69	·07
2	16	7	—	76	60	—
3	10	−5	—	70	50	—
4	16	9	0·02	65	55	1·07
5	8	−2	—	80	50	0·01
6	19	0	—	69	56	0·20
7	22	16	0·04	67	57	0·05
8	19	11	—	71	48	0·03
9	20	6	—	77	50	—
10	12	−5	—	84	54	—
11	20	6	0·02	76	66	0·65
12	12	2	—	78	57	0·01
13	−4	−12	—	82	59	0·30
14	10	−13	—	83	57	—
15	20	10	—	81	65	0·26
16	36	20	0·01	83	62	0·16
17	20	6	—	77	61	—
18	12	−3	—	76	58	0·08
19	14	0	0·02	80	55	0·09
20	−8	−11	—	79	57	0·01
21	7	−10	0·01	76	52	—
22	3	−4	—	79	54	—
23	14	−4	0·06	84	52	—
24	34	13	—	93	62	—
25	20	4	—	98	64	—
26	26	5	0·08	90	73	0·07
27	16	0	—	92	60	0·02
28	26	8	—	75	60	—
29	39	6	—	84	55	—
30	33	20	—	76	53	—
31	18	3	—	76	57	—

EQUATION OF TIME

Time by the Clock when the Sun is due south.

	Hr.	Min.		Hr.	Min.
January 1	12	3	July 1	12	3
February 1	12	14	July 27	12	6
March 1	12	13	August 1	12	6
April 1	12	4	September 1	12	0
April 16	12	0	October 1	11	50
May 1	11	57	November 1	11	44
May 15	11	56	November 4	11	44
June 1	11	58	December 1	11	49
June 15	12	0	December 26	12	0

THE TWENTY-FOUR-HOUR CLOCK NOTATION

11.20 a.m.	1120
11.5 p.m.	2305
1.16 a.m.	0116
1 a.m.	0100
1 p.m.	1300
10.1 a.m.	1001
12.1 a.m.	0001
12.1 p.m.	1201

VLADIVOSTOCK, 1931, 6 A.M.

	January.		July.	
	° F.	Wind.	° F.	Wind.
1	— 2	C.	63	S.E.
2	14	N.	57	W.
3	30	N.N.W.	59	E.S.E.
4	19	C.	—	—
5	1	N.N.E.	55	C.
6	— 4	N.W.	54	C.
7	— 11	N.	—	—
8	— 9	N.	61	S.E.
9	— 11	N.N.E.	61	S.E.
10	— 20	N.	52	S.S.W.
11	— 17	S.S.E.	54	S.
12	— 8	C.	54	W.S.W.
13	7	C.	55	C.
14	1	C.	57	C.
15	0	C.	57	C.
16	23	C.	57	C.
17	1	N.	57	S.S.E.
18	— 2	C.	61	S.E.
19	— 2	N.N.E.	59	S.E.
20	— 11	N.	61	S.
21	— 2	N.	55	S.S.W.
22	9	C.	57	W.S.W.
23	18	N.	52	S.S.E.
24	28	N.	55	C.
25	1	N.	—	—
26	— 9	N.	63	C.
27	— 8	C.	61	C.
28	0	C.	66	C.
29	14	N.N.E.	72	E.S.E.
30	10	N.	63	S.S.E.
31	27	S.E.	64	S.S.E.

SHANGHAI, 1931, 2 P.M.

	January.		July.	
	° F.	Wind.	° F.	Wind.
1	45	W.N.W.	77	S.W.
2	46	W.S.W.	84	S.W.
3	50	S.S.E.	88	—
4	57	W.N.W.	79	VAR.
5	55	E.N.E.	82	E.S.E.
6	43	N.N.W.	79	W.S.W.
7	41	N.N.W.	84	S.S.E.
8	41	N.N.W.	81	VAR.
9	39	N.N.W.	84	E.S.E.
10	16	N.W.	81	S.E.
11	21	N.W.	84	E.S.E.
12	25	W.N.W.	81	VAR.
13	28	W.N.W.	73	N.E.
14	30	W.S.W.	73	E.
15	28	W.S.W.	75	E.S.E.
16	39	VAR.	79	S.E.
17	37	N.N.E	83	S.S.E.
18	37	W.N.W.	86	S.S.E.
19	41	W.S.W.	84	VAR.
20	41	E.N.E.	84	S.S.W.
21	43	E.	77	W.N.W.
22	46	N.	75	E.
23	43	N.	72	E.S.E.
24	39	E.N.E.	79	E.
25	48	VAR.	73	W.S.W.
26	37	N.N.W.	73	E.S.E.
27	28	W.N.W.	79	N.E.
28	30	W.S.W.	82	VAR.
29	37	VAR.	81	S.W.
30	39	E.N.E.	84	S.S.E.
31	45	E.S.E.	84	S.S.E.

GREAT CIRCLE

Day-and-night line through 66½° N, Longitude 0° on December 21.

Through 66½° N. Latitude, Longitude 0° on December 21.

Noon at Greenwich.

Latitude.	Longitude.
66½° N.	0°.
66° N.	15° E. and W.
63½° N.	30° E. and W.
58½° N.	45° E. and W.
49° N.	60° E. and W.
30½° N.	75° E. and W.
0° S.	90° E. and W.
30½° S.	105° E. and W.
49° S.	120° E. and W.
58½° S.	135° E. and W.
63½° S.	150° E. and W.
66° S.	165° E. and W.
66½° S.	180°

RHUMB LINES

Through the point where the Equator is crossed by the Greenwich Meridian.

Latitude.	Longitude.	Alternative Method. Latitude.	Longitude.
0	0	0	0
14½	15	15	16
28½	30	30	32½
40½	45	45	52
50	60	60	76½
59	75	75	118
66	90		
71	105		
75½	120		

For S.E. line read S. lat. E. long.
For N.E. ,, ,, N. ,, E. ,,
For S.W. ,, ,, S. ,, W. ,,
For N.W. ,, ,, N. ,, W. ,,

WELLINGTON, N.Z. (Altitude 415 feet), 1931

January.	Temperature °F.			Wind.	Rain.	July.	Temperature °F.			Wind.	Rain.
	9 a.m.	Max.	Min.				9 a.m.	Max.	Min.		
1	61	65	56	N.E.	—	1	45	50	36	N.	0·18
2	64	68	59	N.W.	0·02	2	47	51	44	N.N.W.	0·10
3	62	66	59	N.W.	0·03	3	45	54	39	N.W.	—
4	63	65	58	W.N.W.	—	4	50	55	43	N.W.	0·01
5	64	67	56	N.W.	—	5	55	59	50	N.N.W.	—
6	61	64	54	N.W.	0·05	6	49	50	46	W.N.W.	—
7	61	65	54	N.W.	—	7	49	53	41	N.N.W.	0·6
8	62	66	55	N.W.	—	8	47	48	45	S.S.E.	1·87
9	59	65	50	N.W.	0·32	9	42	44	39	E.S.E.	0·31
10	65	66	55	N.W.	—	10	42	44	39	S.E.	0·62
11	59	65	51	W.	0·53	11	42	47	39	C.	—
12	62	65	52	N.W.	—	12	41	50	35	N.	0·03
13	63	70	53	W.N.W.	—	13	50	54	40	N.W.	0·41
14	61	62	55	N.W.	0·02	14	47	50	47	N.W.	0·09
15	59	62	52	N.W.	—	15	47	54	40	S.E.	—
16	59	64	55	N.W.	0·02	16	50	54	46	W.N.W.	—
17	61	64	47	N.W.	—	17	54	59	50	N.W.	—
18	60	63	52	N.	—	18	49	53	46	N.W.	0·01
19	61	65	55	N.W.	0·52	19	46	50	38	N.W.	—
20	62	63	59	N.W.	0·76	20	42	48	37	N.W.	—
21	59	65	55	N.W.	—	21	45	50	34	N.W.	—
22	62	68	55	N.W.	—	22	47	55	43	N.W.	—
23	60	63	52	N.N.W.	—	23	46	50	38	S.E.	0·05
24	62	63	51	N.W.	0·03	24	47	49	44	E.S.E.	0·1
25	60	65	54	N.	—	25	47	49	46	S.S.E.	0·06
26	63	70	57	N.W.	—	26	46	51	45	E.N.E.	0·06
27	61	65	57	N.E.	0·83	27	49	53	45	N.W.	0·03
28	51	55	51	S.E.	0·26	28	47	55	41	N.E.	0·07
29	55	62	45	N.W.	0·45	29	50	54	43	N.W.	—
30	53	57	47	S.E.	—	30	44	50	41	C.	0·48
31	53	61	48	S.E.	—	31	48	54	43	N.W.	0·31

DISTANCES BETWEEN THE MERIDIANS

Latitude.	Miles.	Latitude.	Miles.
0°	69·172	53°	41·719
10°	68·129	54°	40·749
20°	65·026	55°	39·766
30°	59·956	60°	34·674
40°	53·063	70°	23·729
50°	44·552	80°	12·051
51°	43·621	90°	0·000
52°	42·676		

DIMENSIONS OF THE EARTH

Equatorial radius 3963·34 miles.

Clarke, 1880:

(*a*) Equatorial radius 20,926,202 feet.
(*b*) Polar radius 20,854,895 feet.

Ellipticity $\left(\frac{a-b}{a}\right)$ 1 : 293·47.

U.S.A., 1903–6:

Equatorial radius 6,378,283 ± 74 metres.
Ellipticity 1 : 297·8 ± ·9.

DISTANCES BETWEEN THE PARALLELS

Latitude.	Miles.	Latitude.	Miles.
0°	68·704	53°	69·151
10°	68·725	54°	69·163
20°	68·786	55°	69·175
30°	68·879	60°	69·230
40°	68·993	70°	69·324
50°	69·115	80°	69·386
51°	69·127	90°	69·407
52°	69·139		

MERCATOR'S PROJECTION

Distances from the Equator.	(R = radius.)	
Parallel 10	0·176 R.	50 1·011 R.
20	0·356 R.	60 1·317 R.
30	0·549 R.	70 1·736 R.
40	0·763 R.	80 2·437 R.

GRENADA, W.I. (Altitude 509 feet), 1931

	January.						July.				
	Temp. °F.		Wind.		Rain.		Temp. °F.		Wind.		Rain.
	9 a.m.	6 p.m.	9 a.m.	6 p.m.			9 a.m.	6 p.m.	9 a.m.	6 p.m.	
1	79	82	E.	E.	—	1	80	84	S.E.	E.	0·04
2	80	81	E.	E.	0·09	2	81	83	S.E.	E.	0·06
3	80	82	E.	E.	0·05	3	79	81	E.	E.	0·79
4	80	82	E.	E.	—	4	78	82	E.	E.	1·21
5	79	81	E.	E.	0·29	5	79	81	S.E.	E.	0·086
6	78	81	E.	E.	0·13	6	78	80	S.E.	S.E.	0·63
7	79	82	E.	E.	0·06	7	78	81	S.E.	E.	0·39
8	80	81	S.E.	E.	0·39	8	78	83	S.E.	E.	0·16
9	78	79	E.	S.E.	—	9	79	82	E.	E.	0·76
10	80	82	S.E.	E.	0·15	10	79	81	E.	S.E.	0.37
11	78	81	E.	E.	0·09	11	78	82	S.E.	S.E.	0.47
12	79	79	E.	E.	0·06	12	79	83	E.	E.	0.17
13	79	81	E.	E.	0·10	13	79	80	E.	S.E.	0·87
14	79	80	E.	E.	—	14	79	80	S.E.	S.E.	0·95
15	78	80	S.E.	E.	0·04	15	78	81	S.E.	S.E.	0·27
16	79	81	E.	E.	—	16	78	80	S.E.	E.	0·36
17	80	82	E.	E.	—	17	79	80	E.	S.E.	1·08
18	80	81	S.E.	S.E.	—	18	79	80	S.E.	S.E.	1·46
19	79	82	S.E.	S.E.	0·04	19	80	82	E.	E.	0·89
20	78	80	E.	E.	0·10	20	79	81	E.	E.	1·37
21	79	81	E.	E.	0·30	21	79	81	E.	E.	0·77
22	78	80	E.	E.	0·20	22	80	82	E.	E.	0·86
23	79	82	E.	E.	—	23	81	82	S.E.	S.E.	0·14
24	78	81	E.	E.	—	24	81	82	E.	E.	0·06
25	79	82	E.	E.	—	25	80	80	E.	E.	0·03
26	80	81	E.	E.	—	26	82	83	E.	E.	0·53
27	80	82	E.	E.	—	27	82	83	E.	S.E.	0·89
28	80	81	E.	E.	—	28	81	82	E.	E.	0·69
29	80	82	E.	E.	—	29	80	81	E.	E.	0·56
30	80	81	E.	E.	—	30	80	82	E.	S.E.	0·19
31	79	82	E.	E.	0·34	31	80	81	E.	E.	0·23

TIMES AND DISTANCES

Sidereal Year, 365 days 6 hours 9 minutes 9 seconds.
Tropical Year (Midsummer to Midsummer), 365 days 5 hours 48 minutes 46 seconds.
Sidereal Day, 23 hours 56 minutes 4 seconds.
" Slant " of Earth's axis, 23° 27′ 5″.
Mean distance between Earth and Sun, 92,900,000 miles.
Distance between Earth and Moon :
Roughly a quarter of a million miles.
Greatest, 252,710 miles.
Least, 221,463 miles.
Mean, 238,860 miles.
Full Moon to Full Moon 29·53 days.
Moon's mass $\frac{1}{82}$ of Earth's mass.

ENGLISH COUNTY STATISTICS, 1932

County	Area in sq. miles.	Population (1931). (Add ooo.)	Sheep. (Add ooo.)	Cattle. (Add ooo.)	Wheat. Acres.
Bedfordshire . .	473	220	82	42	25,900
Berkshire . .	713	311	95	66	24,808
Buckinghamshire .	749	271	216	91	16,731
Cambridgeshire .	493	140	77	26	41,841
Isle of Ely . .	372	77	12	22	43,426
Cheshire . .	1,009	1,087	115	203	9,598
Cornwall . .	1,357	317	324	237	8,112
Cumberland . .	1,520	262	694	171	268
Derbyshire . .	1,014	757	153	155	13,846
Devonshire . .	2,598	732	912	327	20,963
Dorsetshire . .	977	239	189	113	13,991
Durham . .	1,001	1,486	292	92	12,908
Essex . . .	1,523	1,755	223	110	84,837
Gloucestershire .	1,237	785	343	157	24,940
Hampshire . .	1,479	1,014	158	102	35,103
Isle of Wight .	147	88	21	18	2,923
Herefordshire .	842	111	437	122	14,107
Hertfordshire .	632	401	89	48	35,667
Huntingdonshire .	367	56	65	27	29,837
Kent . . .	1,525	1,219	890	105	27,326
Lancashire . .	1,708	5,039	403	235	14,709
Leicestershire .	819	541	312	157	14,185
Lincolnshire (Holl.)	411	92	23	33	36,767
Lincolnshire (Kest.)	728	110	197	63	47,356
Lincolnshire (Lind.)	1,502	422	483	136	89,977
London . .	117	4,397	10	10	1,199
Middlesex . .	232	1,638	10	10	1,199
Monmouthshire .	540	434	251	57	3,281
Norfolk . .	2,037	504	298	144	91,189
Northamptonshire	909	309	423	138	28,315
S. of Peterborough	84	51	20	7	5,028
Northumberland .	2,010	756	1,201	170	4,398
Nottinghamshire .	827	712	168	90	34,153
Oxfordshire . .	744	209	183	83	30,047
Rutlandshire .	152	17	76	19	3,945
Shropshire . .	1,347	244	573	236	18,747
Somersetshire .	1,616	475	410	255	17,845
Staffordshire . .	1,128	1,431	223	192	15,197
Suffolk, E. . .	859	294	111	62	50,052
Suffolk, W. . .	611	106	106	27	41,214
Surrey . . .	708	1,180	46	44	7,031
Sussex, E. . .	815	546	190	89	10,641
Sussex, W. . .	631	223	108	58	17,563
Warwickshire .	880	1,535	319	129	18,661
Westmorland .	979	65	444	77	92
Wiltshire . .	1,350	303	257	161	32,614
Worcestershire .	740	420	199	84	12,350
Yorkshire, E. .	1,158	483	460	96	66,779
Yorkshire, N. .	2,125	469	787	196	23,982
Yorkshire, W. .	2,627	3,352	722	272	49,346

STATISTICS FOR SCOTLAND AND WALES, 1932

Scotland

County.	Area in sq. miles.	Population (1931). (Add ooo.)	Sheep. (Add ooo.)	Cattle. (Add ooo.)	Wheat. Acres.
Aberdeen	1,972	295	411	171	—
Angus	874	264	218	49	10,889
Argyll	3,110	63	715	50	1
Ayr	1,132	293	410	112	710
Banff	630	55	115	43	—
Berwick	457	27	412	25	1,435
Bute	218	19	43	9	—
Caithness	686	26	190	19	—
Clackmannan	55	32	14	4	151
Dumfries	1,072	153	581	71	46
Dumbarton	246	79	70	13	288
East Lothian	267	48	173	15	5,003
Fife	504	291	162	46	10,898
Inverness	4,211	80	504	43	25
Kincardine	381	41	81	27	1,034
Kinross	82	8	37	6	192
Kirkcudbright	899	29	401	59	41
Lanark	879	1,603	240	72	1,668
Mid-Lothian	366	516	201	18	4,631
Moray	477	40	57	23	642
Nairn	162	8	17	6	—
Orkney	376	22	69	37	—
Peebles	348	15	208	7	4
Perth	2,494	120	662	68	6,491
Renfrew	240	297	48	24	1,287
Ross and Cromarty	3,089	67	330	37	568
Roxburgh	666	43	586	25	859
Selkirk	267	22	187	4	5
Stirling	451	171	130	33	1,171
Sutherland	2,028	17	214	8	—
West Lothian	120	86	27	12	1,985
Wigtown	487	29	152	60	—
Zetland	551	24	169	11	—

Wales

Anglesey	276	49	166	54	113
Brecknock	733	58	505	41	807
Cardigan	692	55	328	70	1,718
Carmarthen	920	179	324	123	1,046
Carnarvon	572	130	320	54	93
Denbigh	666	157	511	84	1,783
Flint	264	112	153	48	867
Glamorgan	813	1,226	335	66	1,847
Merioneth	660	43	432	37	86
Montgomery	797	48	535	83	4,385
Pembroke	614	87	174	105	714
Radnor	458	21	327	36	690

HEIGHT OF TIDE DURING DECEMBER 1934

	Avonmouth.	Dover.	Honolulu.	Liverpool.	Immingham.	Shanghai.	Yokohama Bay.	Halifax, N.S.	St. John, N.B.	Lisbon.	Brest.	London Bridge.
1	31·8	15·2	1·4	22·8	16·0	9·4	4·9	5·4	22·0	8·6	19·4	17·7
2	33·3	15·8	1·6	23·8	16·9	9·3	5·2	5·6	22·9	9·0	20·0	18·4
3	35·2	16·6	1·8	24·9	18·0	9·8	5·2	5·8	23·8	9·3	21·0	18·9
4	37·3	17·3	2·0	26·1	19·0	10·5	5·2	6·1	24·7	9·6	22·0	—
5	39·0	17·6	2·2	27·4	19·9	11·3	5·6	6·3	25·5	10·1	22·8	20·0
6	40·3	18·1	2·3	28·4	20·4	12·2	5·6	6·5	26·1	10·5	23·5	20·8
7	41·2	18·7	2·3	29·1	21·1	13·0	5·9	6·6	26·7	10·9	24·1	21·3
8	41·7	18·8	2·3	29·7	21·2	13·6	5·9	6·7	26·9	11·1	24·4	21·6
9	41·6	19·2	2·2	29·9	21·2	13·7	5·6	6·6	26·8	11·1	24·4	21·8
10	41·2	19·0	2·0	29·7	21·0	13·5	5·6	6·5	26·2	11·0	24·1	21·6
11	40·2	18·6	1·8	28·9	20·6	13·0	5·2	6·2	25·5	10·6	23·5	21·0
12	38·5	17·8	1·5	28·1	19·8	12·1	5·2	6·1	24·5	10·2	22·6	20·8
13	36·8	17·5	1·3	26·9	18·9	11·1	4·9	6·0	23·9	9·8	21·8	20·3
14	35·4	16·7	—	26·0	—	10·2	4·9	5·9	23·6	9·5	21·3	19·7
15	34·8	16·3	1·5	25·7	18·0	9·5	4·9	5·9	23·8	9·3	21·0	19·1
16	35·2	16·4	1·8	25·9	17·8	9·4	4·9	5·9	24·1	9·2	21·0	19·3
17	36·3	16·7	1·9	26·4	18·1	9·9	5·2	6·0	24·7	9·3	21·2	19·7
18	37·5	17·0	2·0	26·8	18·8	10·6	5·2	6·1	25·0	9·5	21·7	—
19	38·6	17·2	2·1	27·1	19·3	11·3	5·2	6·1	25·2	9·8	22·1	19·9
20	39·0	17·6	2·1	27·5	20·0	12·0	5·6	6·1	25·2	10·0	22·8	20·5
21	39·4	18·3	2·1	27·8	20·2	12·4	5·6	6·1	25·1	10·1	23·1	20·9
22	39·6	—	2·0	27·7	20·2	12·5	5·6	6·1	24·9	10·2	23·3	21·1
23	39·3	18·3	1·9	27·6	20·1	12·6	5·6	6·0	24·5	10·1	23·1	20·9
24	38·8	17·7	1·8	27·4	20·0	12·4	5·2	5·9	24·0	10·0	22·8	20·7
25	37·8	17·4	1·6	26·9	19·4	12·0	5·2	5·6	23·6	9·7	22·3	20·4
26	37·0	17·2	1·4	26·3	18·9	11·7	5·2	5·5	23·0	9·4	21·7	20·0
27	36·1	16·6	1·2	25·6	18·2	11·2	5·2	—	22·3	9·1	20·8	19·7
28	34·8	15·8	1·1	24·6	17·6	10·6	4·9	5·5	22·0	8·8	20·2	19·1
29	33·4	15·5	1·4	23·7	16·9	9·7	4·9	5·5	22·0	8·5	19·5	18·4
30	32·2	15·0	—	22·8	—	8·8	4·9	5·5	22·1	8·3	19·2	17·9
31	31·9	14·7	1·6	22·7	16·4	8·7	4·9	5·5	22·6	8·5	19·4	17·6

New Moon 6 d. 17 h. 25 m.
First Quarter 13 d. 10 h. 52 m.

Full Moon 20 d. 20 h. 53 m.
Last Quarter 29 d. 02 h. 08 m.

DECLINATION OF THE SUN

Jan. 1	23° S.	Mar. 7	5½° S.	May 6	16° N.	July 5	23° N.	Sept. 8	6° N.	Nov. 7	16° S.
6	22½	12	3½	11	17½	10	22½	13	4	12	17½
11	22	17	1½	16	19	15	21½	18	2	17	19
16	21	21	0	21	20	20	21	23	0	22	20
21	20	22	0° N.	26	21	25	20	24	0° S.	27	21
26	19	27	2	31	22	30	18½	28	1½	Dec. 2	22
31	17½	Apr. 1	4	June 5	22½	Aug. 4	17½	Oct. 3	3½	7	22½
Feb. 5	16	6	6	10	23	9	16	8	5½	12	23
10	14½	11	8	15	23¼	14	14½	13	7½	17	23¼
15	13	16	10	20	23½	19	13	18	9½	21	23½
20	11	21	11½	21	23½	24	11½	23	11	22	23½
25	9½	26	13	25	23½	29	9½	28	13	26	23½
Mar. 2	7½	May 1	15	30	23	Sept. 3	8	Nov. 2	14½	31	23

ST. LUCIA (W. INDIES) 8 A.M. OBSERVATIONS IN 1931. (ALTITUDE 17 FEET.)

	January.			January.			July.			July.	
	°F.	Wind.		°F.	Wind.		°F.	Wind.		°F.	Wind.
1	78	N.E.	17	76	N.	1	82	S.E.	17	82	N.E.
2	76	N.E.	18	76	N.E.	2	84	E.	18	82	N.E.
3	78	N.E.	19	76	N.E.	3	83	E.	19	83	N.E.
4	78	N.E.	20	78	N.E.	4	83	N.E.	20	81	N.E.
5	78	N.E.	21	78	N.E.	5	81	N.E.	21	82	N.E.
6	75	VAR.	22	77	N.E.	6	78	S.E.	22	79	N.E.
7	77	E.	23	75	N.E.	7	82	E.	23	80	VAR.
8	76	S.E.	24	76	N.E.	8	78	S.E.	24	82	N.E.
9	76	S.E.	25	77	N.W.	9	78	S.E.	25	81	N.E.
10	79	N.E.	26	76	N.E.	10	82	E.	26	82	N.E.
11	75	E.	27	75	VAR.	11	80	VAR.	27	81	N.E.
12	76	VAR.	28	78	N.	12	81	VAR.	28	82	N.E.
13	73	VAR.	29	78	N.E.	13	82	N.E.	29	82	N.E.
14	75	N.E.	30	77	S.E.	14	81	E.	30	80	VAR.
15	74	VAR.	31	75	N.E.	15	81	E.	31	82	N.E.
16	74	N.				16	81	N.E.			

FAHRENHEIT AND CENTIGRADE

°F.	°C.	°F.	°C.	°F.	°C.
0	— 17·8	50	10	95	35
14	— 10·0	59	15	104	40
30	— 1·1	68	20	113	45
32	0	77	25	122	50
41	5	86	30	212	100

RAINFALL AND ALTITUDE

In Britain there is a general increase of rainfall with altitude, though if we know what the fall is at the base of the mountain there is no rule by which the amount at the summit can be calculated.

A3. From the table below find what the increase of rainfall is for every hundred feet in going up from Fort William to Ben Nevis.

A4. Find similarly the increase per hundred feet between Aberystwith and (*a*) Plynlimmon, (*b*) Goginan, (*c*) Cwmsymlog, (*d*) Waenbwll.

A5. Find the increase of rainfall for each hundred feet between (*a*) Gawthorpe and Ogden Reservoir, (*b*) Gawthorpe and Sabden.

The stations[1] in each group are in the same district and face the same direction.

Sussex

	Altitude in feet.	Average annual rainfall.
Bognor	15	26·0
Eastham	230	29·5
Selhurst	300	32·2
Bapton	554	37·0

Cardigan

	Altitude in feet.	Average annual rainfall.
Aberystwith	15	35·6
Goginan	290	46·2
Cwmsymlog	800	55·5
Waenbwll	1380	67·4
Plynlimmon	1740	94·0

Lancashire

	Altitude in feet.	Average annual rainfall.
Gawthorpe	316	41·4
Sabden	500	43·3
Ogden Reservoir	935	46·2

Scotland

	Altitude in feet.	Average annual rainfall.
Fort William	12	75·9
Ben Nevis	4407	162·6

[1] Figures are quoted from "Rainfall of the British Isles," Salter, Univ. of London Press.

APPENDIX

THE ANGULAR MEASUREMENT OF LATITUDE AND LONGITUDE

IF telescopes are pointed to a star from any two places on the surface of the earth, their directions are parallel because of the immense distances at which all the stars are situated (Fig. 201). But if

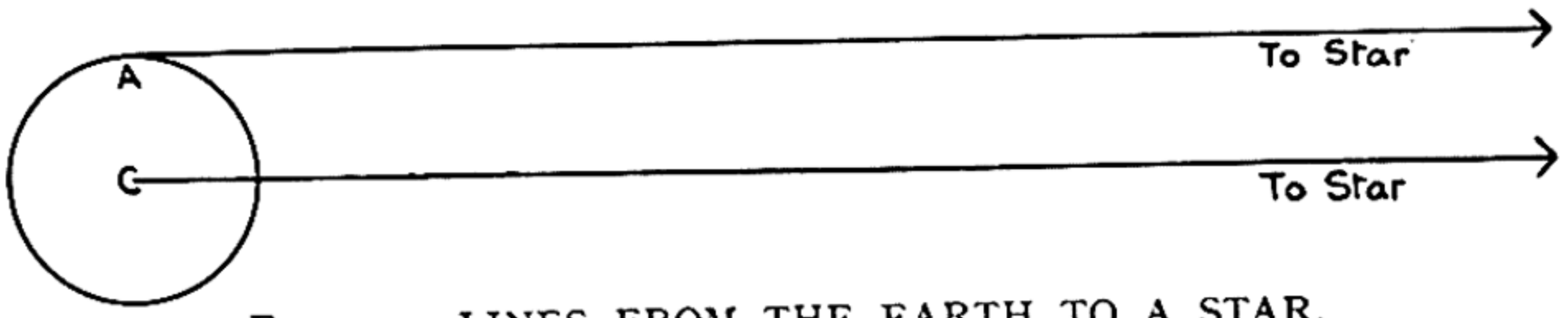


FIG. 201.—LINES FROM THE EARTH TO A STAR.

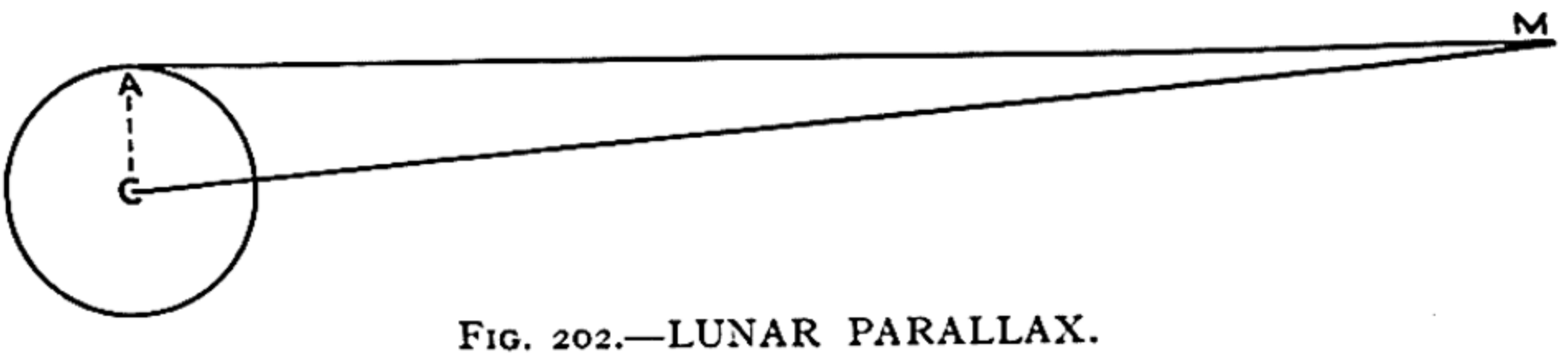


FIG. 202.—LUNAR PARALLAX.

the telescopes are pointed to any spot on the moon they incline slightly towards because the moon is comparatively close to the earth (Fig. 202).

Because of this inclination, all calculations regarding the position of the moon are made as though the observation had been carried out at the centre of the earth: latitude and longitude are then angular measurements at the centre of the earth and not distances along its surface, as they are in Chapter Five.

In Fig. 202 O is the centre of the earth, A a point on its surface, and M a point on the moon. The inclination of AM to OM is the lunar parallax, and if the diagram be drawn approximately to scale by making OM sixty times OA, the angle AMO will be practically one

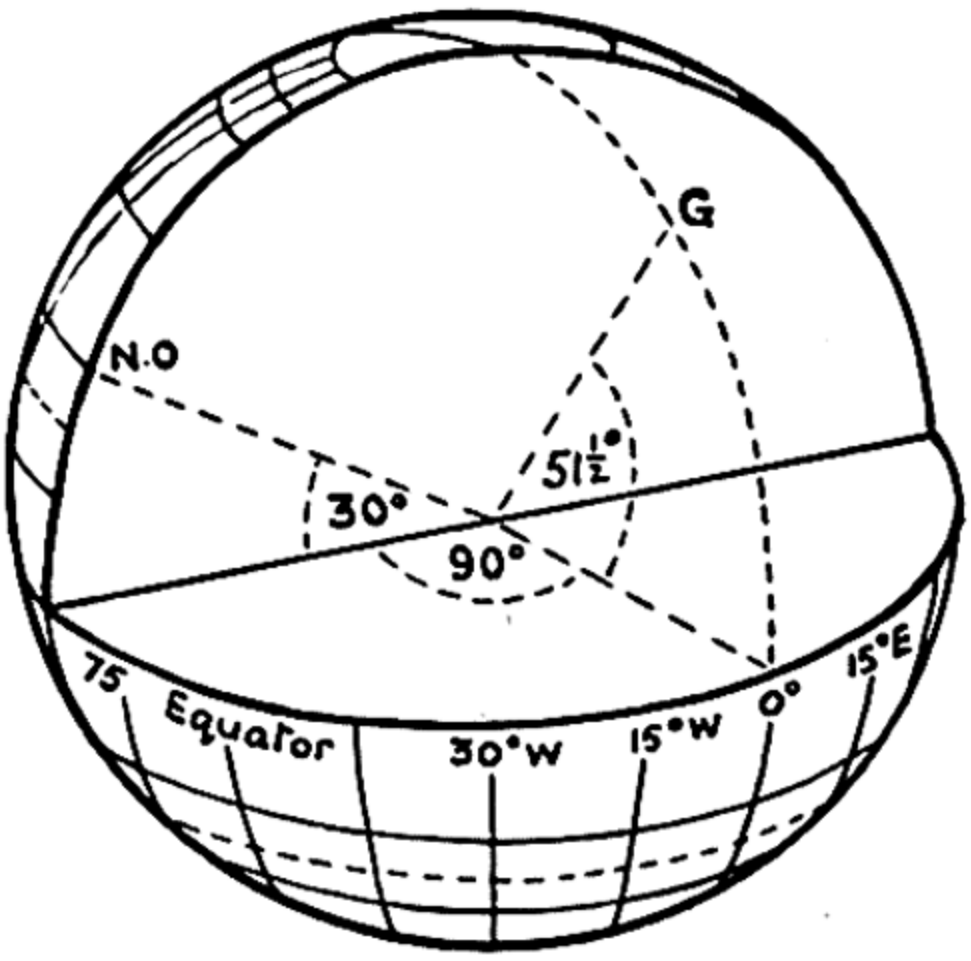


FIG. 203.—LATITUDE AND LONGITUDE.

degree (see Fig. 196). The corresponding solar parallax is one-fourhundredth of a degree, but small as this is it must be taken into account in some calculations.

The lines in Fig. 203 are taken from the picture of the globe on page 44. A section has been removed by cutting through the Equator to the centre and then through meridians 90E. and 90W. The curved dotted line is the Greenwich meridian.

The longitudes are measured in the plane of the Equator, while the latitude of any place is measured in the plane of its meridian. Thus the positions of Greenwich (G) and New Orleans (NO) are :

Greenwich	..	..	..	Lat. 51½, Long. 0.
New Orleans	..	..	..	Lat. 30N., Long. 90W.

ADDENDUM

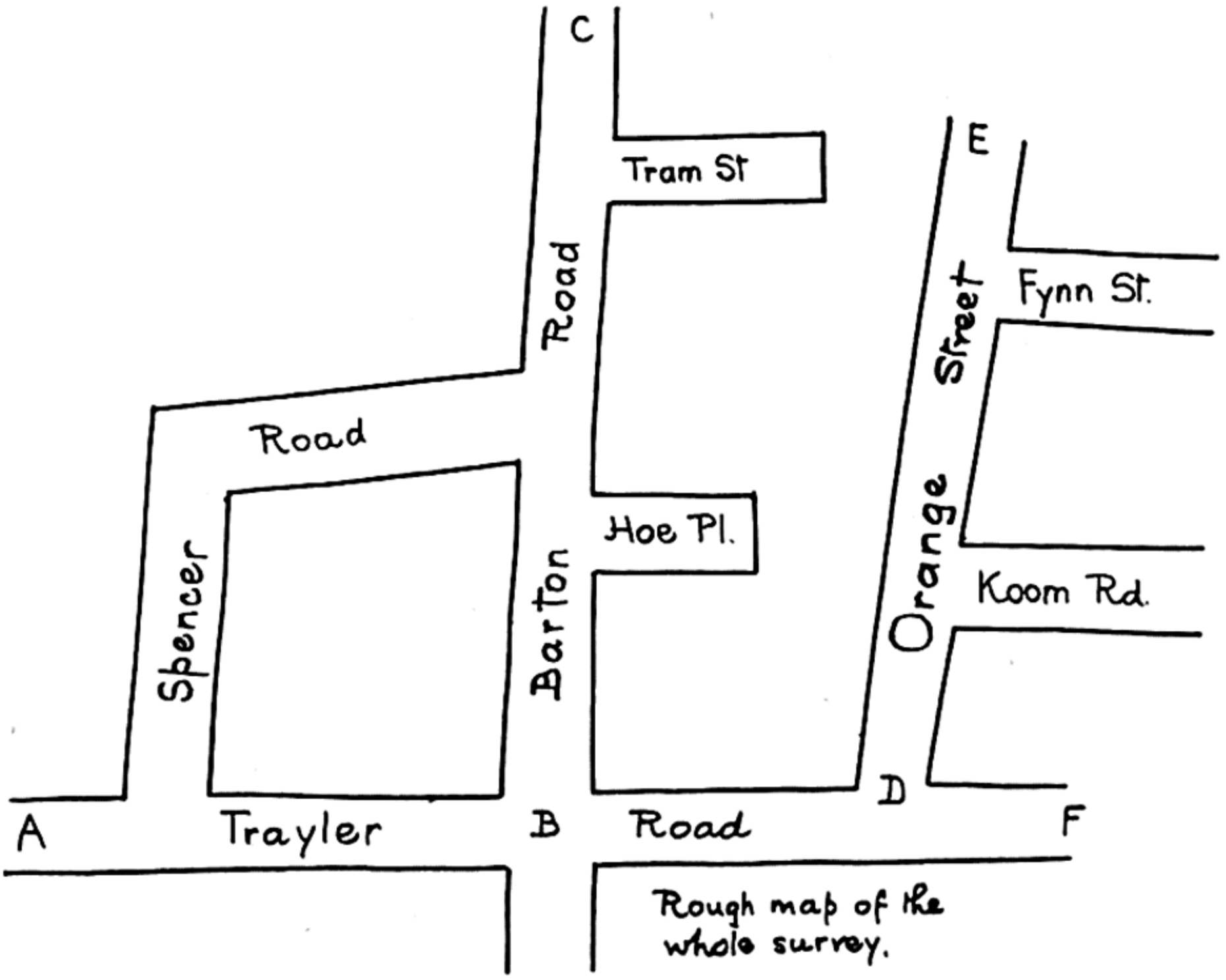


FIG. 204. (See page 173.)

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